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Dr. Emory W. Hunt
Tenth President of Denison University, 1902–1913

HISTORY OF THETA CHAPTER OF OHIO PHI BETA KAPPA

1911–1936

WILLIS A. CHAMBERLIN
Chapter Historian

Received March 2, 1937; published June 1, 1937

TO EMORY W. HUNT, D.D., LL.D.

PRESIDENT OF DENISON UNIVERSITY, 1902–1913

IN GRATEFUL APPRECIATION OF HIS EFFORTS

IN BEHALF OF THETA CHAPTER OF OHIO

OF PHI BETA KAPPA

FOREWORD

The quarter-centennial of the founding of *Theta* Chapter of Ohio of Phi Beta Kappa marks a development which merits more than casual recognition. The events of this formative period of the Chapter are important not only in the history of the Society, but also as reflecting the life of Denison University. It seems fitting that they should be recorded in permanent form before the remembrance of them is blurred by lapse of time.

The materials for this study lay mostly in bundles of letters and documents preserved in various places. Many letters relating to the proceedings before and after the establishment of the Chapter were placed in the writer's hands several years ago by Dr. Emory W. Hunt. Other correspondence was turned over to him by Dr. Francis W. Shepardson. Valuable letters and records were in the keeping of Dr. Millard Brelsford, Secretary of the Board of Trustees of Denison, who made them available for inspection and use. Some links in the narrative were discovered by Dr. O. M. Voorhees, Historian of Phi Beta Kappa, who thus gave an added incentive to this work. Dr. Wallace Cathcart, Director of the Western Reserve Historical Society, gave essential information concerning two pioneer professors of Denison. Lastly, Dr. F. C. Waite, Historian of *Alpha* Chapter of Ohio of Phi Beta Kappa, gave reliable information concerning facts related in Chapter II of this account. At hand for frequent use were the histories of Denison and other printed records, to which reference is made in the proper places.

Dr. Francis W. Shepardson has read over the manuscript several times and suggested many valuable points out of his extensive knowledge of Denison history. Dr. E. J. Shumaker gave the manuscript a careful revision and offered suggestions for its improvement in expression. Dr. L. R. Dean of the Committee on Publication, and Dr. F. J. Wright, President of the Chapter, gave wise assistance. It is a pleasure to acknowledge their coöperation. Dr. W. C. Ebaugh's care in editing and publishing the work is also appreciated.

W. A. C.

Granville, Ohio
March 1, 1937.

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Chapter I

INTERTWINING STREAMS

Various influences converged in the founding of The Granville Literary and Theological Institution which opened its doors to students on December 13, 1831. Religious and economic motives were predominant; personal and collective interests were involved, while local and national conditions favored the movement just at that time. It was the product of that great religious and intellectual awakening which marked the early decades of the nineteenth century. The enterprise originated in the need for an educated ministry in the Baptist denomination of this frontier state. Baptist leaders in the East who visited their brethren of Ohio found a deplorable lack of training in the churches (*1*). The desire to improve this condition was the immediate cause of the undertaking. But the Institution was rooted in deeper soil than this. It grew out of the belief in thorough education as a means for the development of moral and intellectual character. The pioneers of the new West were firm in the conviction of the moral power of sound education. This belief was a part of their New England heritage. It was fortunate for the Middle West that the New England influence dominated its organization and shaped its religious and educational enterprises.

Granville, which was a part of Massachusetts set down in the midst of this new territory, was fitted by this circumstance to receive the infant college. The Granville Institution was a scion of the New England tree. More specifically it was the daughter of Brown University. Both educational enterprises were based on the conviction that

> **Institutions for liberal Education are highly beneficial to Society, by forming the rising Generation to Virtue Knowledge & useful Literature & thus preserving to the Community a Succession of Men duly qualify'd for discharging the Offices of Life with Usefulness and reputation (*2*).**

The first president and other leaders in organizing the college at Granville were graduates of Brown University, and were imbued with the ideals of their *alma mater*. They set up the administration and the policy of the new institution after the pattern of their eastern model. The aim was to provide a liberal training based on sound scholarship. The Ohio Baptist Education Society, which was organized for the purpose of securing the College, expressly states in Article II of its revised constitution adopted at the meeting in Lancaster, May 26, 1831:

> The object of this society shall be to promote sound literature and science, including the literary and theological improvement of pious young men for the ministry (*3*).

It is presumable that this statement of the broad cultural aim of the College was made by Dr. Jonathan Going of Worcester, Massachusetts, a graduate of Brown University, who was present as a visitor of the Convention and was appointed on the committee of constitution. If this conjecture is true, Dr. Going's recommendation is another evidence of the influence of the college at Providence (*4*).

The faith in sound scholarship as a moral force, which animated the pioneers of Denison University, had taken concrete form in that society whose motto precisely expressed that sentiment and of which the initial letters form the name, *Phi Beta Kappa*. It is evident from a reading of the minutes of the early meetings of this organization, that the "happy spirit and resolution of attaining the important ends of Society" which possessed the minds of John Heath and his four companions in founding the Phi Beta Kappa at the College of William and Mary on December 5, 1776, was their belief in humanistic training as a preparation for life. This was succinctly stated in their motto: *Philosophy the Guide of Life*, in which the word philosophy is used in its primary meaning of love of learning. This ideal was to be realized in the way of virtue, friendship, and literature. In the quaint words of the initiation service:

> They (the founders) planted the scion, from which has grown this tree. . . . It was ingrafted on the stock of friendship in the soil of virtue, enriched by Literature (*5*).

Literature was a very real aim of the Society, which they cultivated by means of debates and other exercises at each meeting. But they used the term also in its broader meaning of wisdom or learning, as it was used in the charter of Brown University and in Article II of the constitution of the Ohio Baptist Education Society. By associating together they sought to promote friendship, virtue, and the love of learning. Their chapter disbanded in consequence of the tumults of the War in 1781, but already Elisha Parmale, one of their number, had secured permission to plant branches in the two New England colleges which he had attended, Yale and Harvard. Thus the torch lighted at the altar of William and Mary was rekindled by him at Yale on November 13, 1780, and at Harvard, his *alma mater*, on September 5, 1781. These two *Alphas* established jointly a third branch at Dartmouth in 1787. Years later the Fraternity was planted at other colleges: at Union, 1817, at Bowdoin, 1825, at Brown in 1830. But the spirit of Phi Beta Kappa radiated beyond the borders of these few colleges. Through its members it permeated all the fields of educational work. It is a noteworthy coincidence that this Society was established at Brown University in 1830, just a year before the opening of the Granville Institution. It can hardly be doubted that the fathers of Denison University, who had seen the founding of Phi Beta Kappa at Brown, were actuated with the desire to realize the ideals of this Society in the young college that they were establishing. It is here appropriate to state, what has not been mentioned in previous historical accounts of Denison, that the presidents and most of the professors in the formative years of the College were members of Phi Beta Kappa in the eastern colleges from which they came. So it is easy to understand that they grafted the ideals of this Society into the young branch of learning in the West. In this way, through living representatives, the traditions of this honorable fraternity were transplanted to our midst. In these men "love of learning" was the "guide of life," and the principles of "friendship, virtue and literature" were also exemplified by them. In a real and practical sense they impressed these ideals on the life of this College.

As we look back upon their work, we feel that it is no exaggeration to say that Phi Beta Kappa has exerted through them a dynamic influence in shaping the character of Denison University, guiding its followers upward and onward in the pursuit of truth.

It is now opportune to inquire who these leaders were, to whom reference is made, and to characterize briefly their work in an attempt to evaluate their service in the cause of humanistic culture in the Middle West.

John Pratt, who was called to the leadership of the new institution and as Professor of Languages at its opening in 1831, embodied in a notable degree these ideals that have been mentioned. His efforts after his graduation from college alternated between preaching and teaching, or combined these two callings. At the time of his appointment to the Granville Institution he was principal of an academy at South Reading, Massachusetts. His graduation from Brown University in 1827 preceded by three years the inauguration of the Phi Beta Kappa chapter there. But when it was established, John Pratt was one of the alumni to be elected to membership (*6*). He was in full sympathy with the aim of the Trustees of the Granville Institution, which they declared in their annual report of October 6, 1832:

> It is our purpose to furnish the means of obtaining a thorough classical and English education, which shall not be inferior to what can be obtained in any institution, of whatever name, in the western country (*7*).

Professor Pratt was remarkably successful in achieving this objective. In his report to the Trustees concerning the student body, which he made at the close of the second year of his service at Granville, he says:

> The great body of the members have exhibited a very estimable character for assiduity and perseverance in their studies, and seem to regard, with high and spontaneous respect, the doctrine strenuously inculcated by the instructors in relation to the manner of producing sound scholarship. Much has, therefore, been expected of them, nor has the expectation been lost in disappointment (*8*).

It is evident that the principles of sound scholarship were implanted in the Granville students by President Pratt and his

colleagues. It was his great work to organize the institution and to pilot it through these dark and discouraging years, when there was almost nothing to count on but devotion to the cause of truth on the one hand and eagerness to learn on the other. Owing to a disagreement with one of the professors regarding his administration of the Institution, Professor Pratt withdrew from the presidency in 1837. His growing reputation for scholarship and administrative ability brought him a call to Tecumseh, Michigan, as head of one of the branch colleges organized by the University of Michigan under its comprehensive charter. He was soon recalled to Granville to his old position of Professor of Languages (*9*). He continued in this professorship for more than twenty years, during which he was twice called to preside *ad interim* over the College. Thus he gave nearly thirty years of the best part of his life to this institution. Surely his spirit, rising from the quiet cemetery on the Hill, still broods benevolently over this place.

Of the four professors who were associated with President Pratt, all of them were distinguished scholars and three of them continued the Phi Beta Kappa succession.

Samuel Budd Swaim was called to be the first Professor of Moral Philosophy and Theology when that professorship was established in 1833 (*10*). He was a graduate of Brown in the class of 1833 and was elected to alumni membership in the chapter of Phi Beta Kappa in 1849. He was evidently a strong man intellectually, impressing his personality on his followers. His disagreement with President Pratt (referred to above) led to his resignation after three years of service. But this did not signify his separation from the interests of the College, for in the same year he was elected president of the Ohio Baptist Education Society and a trustee of the Granville Institution (*11*).

Asa Drury, Professor of Languages, 1834–1836, was a Yale graduate and a member of the Yale chapter of Phi Beta Kappa. From a contemporary record made by one of the students, it appears that Professor Drury was a man of ardent feelings and outspoken in his beliefs. Just at this time there was much agitation in Granville over the slavery question and a clash

occurred between the abolitionists and their opponents. It is very likely that the termination of Drury's service with the College after only two years was precipitated by southern students of the institution, who objected to his bold abolitionist views (*12*). He left Granville to become Professor of Greek at Cincinnati College.

George Cole, an alumnus of Brown in 1834 and a member of the *Alpha* (Rhode Island) chapter of Phi Beta Kappa, was another of the pioneer professors at Granville. He occupied the chair of Mathematics and Natural Philosophy from 1835 to 1838. He left the Institution to become editor of the *Cross and Journal* (later called the *Journal and Messenger*), the denominational paper which had been established by John Stevens in 1831 in Cincinnati. He maintained a vital connection with the Granville Institution for several years after his withdrawal from the faculty and his name appears on important committees of the Board of Trustees.

Pascal Carter was the fourth member of the quadrumvirate of the faculty who are credited for sustaining the College during the early years of its history. He was graduated from Middlebury College (Vermont) in 1829. From the principalship of the South Reading Academy, where he succeeded John Pratt, he came to Granville in 1832. For the second time within a year this Academy was called upon to furnish the leaders of the young institution in Ohio. Professor Carter was the first man called to the assistance of Professor Pratt and remained for twenty-two years, from 1832 to 1854. He was "a ready and thorough teacher" whose ability was a steady asset of the Institution during these formative years. His career substantiated the testimony that was given of him by an acquaintance at the time of his call to Granville,

> as a gentleman of unblemished religious and moral character and of mild and amiable manners, as a thorough and finished scholar and as an industrious and faithful teacher (*13*).

Jonathan Going was a happy selection as a successor of John Pratt in the presidency of the Granville Institution. He was a

strong character and a firm believer in education. By good fortune he had taken a leading part in the founding of this new enterprise. On a tour of the West he was present at the meeting of the Ohio Baptist Education Society in Lancaster in 1831, at which it was decided to start the Institution. He was influential in determining Granville as the site of the undertaking. It is altogether probable, as stated above, that he drafted the article defining the liberal character of the College. A graduate of Brown in 1809, a Phi Beta Kappa, a Baptist pastor, he was an exponent of the best religious and scholarly traditions of New England when he came to Granville. He was familiar with the administration of colleges, for he was a trustee of Brown University and of Amherst College and one of the founders of the Newton Theological Institution and of Worcester Academy (*14*).

He was a born teacher, who used his pastor's study as a place of private instruction. He had caught the idea of the supreme importance of the West in our national development, and he spent several years of his life in organizing and guiding the Baptist Home Mission Society to serve this great domain. He was the best man that could have been chosen for the position at Granville. He was a vital link between New England and the West, uniting in his character the finest elements of Eastern training, which he was eager to impart to the growing West. However low the resources of the Granville Institution were, he threw into the task of the presidency all his force and energy, literally wearing himself out. His ideals in respect to scholarship were those of Phi Beta Kappa. He incorporated them in his daily work. He had two fundamental policies: "One was to make the institution adapted to the needs of the new West; the other to keep the standard of instruction as high as that of the best colleges of the land (*15*)." He died in office on November 9, 1844.

At the same time that Dr. Going was elected President, the appointment of John Stevens as Vice-President was made. He was also Professor of Moral and Intellectual Philosophy and Principal of the Literary Department. The triple title was not

an empty honor but designated three positions whose combined functions he was expected to perform. As Vice-President he was charged with the responsibility of administration, while Dr. Going was absent on his long trips in the interests of the College. In this respect he had almost equal responsibility with the President. His place as Principal of the Literary Department was not unlike that of a Dean at the present time. In this capacity he engaged professors (*16*). It may be assumed from passages in his letters that he had supervision of the scholastic work. If this is correct, it indicates the foresight of the Trustees in creating at this early date such a position.

Professor Stevens was graduated from Middlebury College (Vermont) in 1821 with second honors of his class. Years afterward he became an alumnus member of the Phi Beta Kappa, when the *Beta* of Vermont was organized. He prepared for the ministry at the Andover Theological Seminary, transferring to the Baptist belief during that time. He turned, however, to teaching instead of preaching. After several years' experience in teaching, notably at the South Reading Academy, he went west to Cincinnati, where he started the denominational paper later called the *Journal and Messenger*. But as a natural teacher he was glad to accept the professorship at Granville in 1838. He left the College after five years to enter the wider field of the agency for Ohio and Indiana of the American Baptist Missionary Union. He was recalled to Denison (as the College was now definitely named) in 1859 as Professor of Latin and Greek and continued in this work (Professor of Latin after 1868) for eighteen years (*17*). At the time of his death in 1877 the *Denison Collegian* closed its high tribute to him in these words:

> Few men will be more missed than Dr. Stevens. The College, in its varied interests, the church, in its varied activities, society, and the world, have all sustained a loss that will be long and deeply felt.

Rev. Silas Bailey, third president of Granville College, was a graduate of Brown, and like his predecessors in the office, a member of the *Alpha* of Rhode Island of Phi Beta Kappa. It was his lot to preside over the institution in a discouraging period.

It received very meager financial support, despite earnest pleas in its behalf. But in the face of these discouragements President Bailey and his colleagues were able to maintain the standing of the College and to make some headway. It was often said during his incumbency, 1846–1852, that Granville College was the equal of any academic institution in the West.

In reviewing the history of these early years of the College at Granville, one cannot but be impressed with the stalwart quality of the men who founded and nurtured it during the beginning of its growth. They were men of outstanding ability, of tremendous energy and unbounded zeal for the cause of Christian education. They challenge our profound admiration by their exalted service.

It is not our purpose to recount the history of the College, which has been so well done by others. The aim of this chapter will have been attained, if it has revealed the current of Phi Beta Kappa influence in the formative years of the institution.

Chapter II

FRUSTRATED EFFORTS

The year 1876 is memorable in United States history on many accounts. It was the centennial year of American Independence, marked by a great exposition in Philadelphia presenting tangible evidence of our progress in arts, science, and industry. In this same year the founding of John Hopkins University at Baltimore signalized a new era of higher education in this country. This university, patterned after German models, was the first institution in the United States to specialize in graduate courses and to rival European universities in these highest reaches of intellectual training. American society, having passed through the hard years of pioneering and gained a degree of comfort, looked with greater favor upon arts and letters. Money was more freely bestowed upon colleges as nurturing centers of culture. The colleges responded with expanding curricula and higher standards of efficiency.

Denison University (as the old Granville Institution had been named in 1856) shared in the stimulation that affected colleges in general. It was forty-five years old and had weathered the storms of misunderstandings which had seriously weakened it in the early years. Its constituents had cast off the indifference which had almost let the institution die of non-support in the 1850's and they had manifested their faith by raising an endowment of one hundred and seventy-five thousand dollars. The present site had been occupied for twenty years and was graced with "the old frame" (one of the original buildings on the farm site) and two large brick halls for dormitories and class-rooms. One of the latter, now called Talbot Hall, was but recently completed. Doane Library was to be erected in 1878, the first of the series of stately buildings at Denison marking the beneficence of generous patrons. Student enrollment had increased to 157, of whom

60 were in the college department. The classes, though small, contained some men who rose later to high eminence in their professions. The curriculum was much extended in comparison with that of the early years. The department of classical languages had been divided into two; a chair of natural science was established; English occupied a prominent place in the curriculum; German and French were required, and a separate professorship of modern languages was established five years later.

Presiding over this aspiring plant was a galaxy of truly eminent men, well-qualified in scholarship, devoted to their work, progressive in disposition and ambitious to maintain the highest standards of attainments. At their head was Elisha Benjamin Andrews, a young man from the East who had been called to Denison the previous year. He was a remarkable man, a natural leader. Of athletic figure and abounding strength, he possessed an inspiring personality. At the age of seventeen he enlisted in the Civil War and fought for over three years until incapacitated by a wound that destroyed the sight of his left eye. After the War he determined to enter the Baptist ministry. He prepared at Brown University, where he was graduated in 1870, ranking fourth in a class which had several prominent members. He was elected to Phi Beta Kappa in his junior year. He was pastor of the Baptist Church at Beverly, Massachusetts, when the call to the presidency of Denison came. Accepting this unexpected opportunity as providential, he devoted himself henceforth to teaching and school administration, in which he gained enviable success. He was "the greatest teacher in my experience" was the comment of President Ernest D. Burton, who was a student at Denison during Andrews' time (*18*).

Associated with President Andrews in what was considered perhaps the chief department of instruction was Dr. William Arnold Stevens as Professor of Greek. But his renown as a classical scholar led to his call to Rochester Theological Seminary. Dr. Andrews turned for the filling of this position to one of his class-mates at Brown, Richard Steere Colwell. No better appointment could have been made. Professor Colwell was a New Englander, an honor student at college, elected to Phi Beta

Kappa in his junior year. He had studied one year in Germany. When he came to Denison in 1877, he was not yet thirty years old. His distinguished career as a teacher of Greek, extending over forty years, was marked by preeminent influence in college and town circles. He served as Dean of the College, 1913–1918, and as Acting-President, 1912–1913.

The chair of English was occupied by Almon U. Thresher. He was a graduate of Amherst, class of 1865, and a member of the Amherst chapter of Phi Beta Kappa. He was called to Denison soon after graduating and remained twenty-five years, until 1892, as Professor of Rhetoric and English Literature.

John Lord Gilpatrick, a graduate of Kalamazoo College, was just beginning his long and distinguished service as Professor of Mathematics and Physics, which was to end only at his sudden death in 1912.

Lewis Ezra Hicks, a young graduate of Denison, who had studied Zoology under Louis Agassiz at Harvard, was Professor of Natural Science. The Latin Professorship was held by Charles Chandler, who was graduated from the University of Michigan in 1871. Students of the two decades during which he remained at Denison admired Professor Chandler as an accurate scholar and a wonderful teacher. His fame brought him a call to a broader field in the University of Chicago. He was elected an alumnus member of Phi Beta Kappa at his *alma mater* in 1908.

George Fitch McKibben was just winning his spurs as an instructor of Greek and Latin. Another young instructor was William Rainey Harper, who later, as a scholar of Hebrew and first President of the University of Chicago, gained imperishable renown as a teacher and administrator.

Granville as a community rose in prestige as an educational center, as if to compensate for its decline in industrial value. It possessed many other centers of culture besides the University, rather intimately connected with this institution. The churches were important in this respect.

The beloved pastor of the Baptist Church was the Rev. W. C. P. Rhoades. He was graduated from Williams College in 1866, where he was elected in his junior year to membership in *Gamma*

(Massachusetts) of Phi Beta Kappa. Outside of the College, he occupied the most influential position in the community as minister of the College Church.[1] He was vitally connected with the College, as pastor, as a Trustee, and as Secretary of the Board of Trustees from 1875 to 1885. He exerted a gracious influence over both young and old, so that long after he left this town his name was held in grateful remembrance.

Two other schools of higher learning for women were located in Granville: the Granville Female College and the Young Ladies Institute. Both filled an honorable place in their sphere. The Young Ladies Institute was under the management of Dr. Daniel Shepardson, one of the most dynamic personalities ever known in Granville, whose influence on the religious and educational life of the community was incalculable.

In this brief sketch we have a picture of the Denison of 1876, a firmly established college, a center of intellectual life, a vigorous, aspiring plant opening to the sunshine of new-found favor. It had a well-chosen faculty of real scholars, a sound nucleus of students, and a balanced curriculum. No wonder that President E. B. Andrews felt that such an institution, whose prominent qualities were religion and scholarship, was worthy of association with those colleges which were bound together in the inspiring bonds of Phi Beta Kappa.

It is an important fact, revealed through the research of Dr. Oscar M. Voorhees, Historian of the Phi Beta Kappa, that President Andrews made an earnest effort for the granting of a charter of Phi Beta Kappa to Denison. First he applied to the chapter of his *alma mater*, Brown, to support his application. His petition was approved, so far as the *Alpha* of Rhode Island was concerned. The reference is found in the *Minutes of the Forty-Seventh Annual Meeting of the Phi Beta Kappa Society* at Brown University, held on June 20, 1876:

> Voted, That the application of President Andrews of Denison University, Granville, Ohio, be granted, and that the approbation of this branch of the Society

[1] The Granville Institution, at its opening in 1831, used the Baptist Church, then standing on the site of the Denison Conservatory of Music, until its own building was completed.

be given, that a charter be granted for a chapter in connection with Denison University.

Such an application was rare, almost an innovation. Although the Society was exactly one hundred years old in that year, it had made little progress among the colleges. It numbered only twenty-two chapters or branches, most of them in New England states and New York. Almost the only exceptions were three branches in Ohio: the *Alpha* at Western Reserve University, the *Beta* at Kenyon, and the *Gamma* at Marietta. The Society had no unified organization nor supreme authority for its spread to other branches. In the charters of Harvard and of Yale, authority was given to these *Alpha* chapters of their respective states to grant charters "for the establishment of other meetings anywhere within your state" (*19*). These chapters (or meetings) on whom this special privilege was conferred, exercised control, by virtue of this prerogative, over the extension of the Society. From that circumstance sprang the practice of regarding the *Alpha* chapter of each state as invested with authority for granting new charters to colleges within its bounds.

Dr. O. M. Voorhees, who reported this early petition of President Andrews, adds this remark:

> So far as I am aware, no reference to it appears in the records of the other *Alphas*. In the Harvard records, we find that an inquiry came in 1870 from Monmouth College in Illinois and from Asbury College in Indiana, on which action was postponed. In 1877, applications were received in behalf of the University of the South and Cornell University. No application of importance was presented after this date until the United Chapters had been organized and were ready to function. . . . You may know whether there were other members of Phi Beta Kappa at Denison at the time. Why the application was not sent to the *Alpha* of Ohio, that had previously authorized the institution of chapters at Kenyon and Marietta, we may not know (*20*).

It is probable that Dr. Andrews did not know of this custom of applying to the *Alpha* of this state for a charter. At any rate, it was natural for him to petition first his own chapter, whose approval would give weight to the application to the Ohio *Alpha*. Later, in fact, he did apply to this chapter at Western Reserve University, as Dr. Voorhees found on further investigation. His request was made in 1878. Also a similar petition was made

the preceding year, 1877, to the *Gamma* of Ohio at Marietta, as was learned on inquiry. The application was approved in the latter case, as the minutes of the meeting of June 25, 1877, record the following item:

> In response to a request by President Andrews of Denison University, Ohio, the consent of this chapter was given to the foundation of a chapter of Phi Beta Kappa at Denison University (*21*).

Apparently encouraged by the approval of the chapters at Brown University and Marietta College, President Andrews presented his petition the third year to the *Alpha* of Ohio, making it this time in the name of the faculty. His request was considered in the meeting of this chapter of June 25, 1878, and action taken according to the following record:

> A petition for the establishment of a branch was presented from Denison University and the following resolution was adopted: Whereas the faculty of Denison University have made a request for the establishment of a *Delta* of the Phi Beta Kappa in that University, resolved that the matter be referred to a committee consisting of Dr. N. P. Seymour, M. C. Read, Esq., and Professor E. W. Morley, to take such action as after inquiry they may deem proper and report to a future meeting of the *Alpha* (*22*).

Of the above-mentioned committee, Professor Seymour was president and M. C. Read vice-president of the chapter. Professor Seymour was called soon afterwards to Yale, and on the same day on which the business meeting of *Alpha* was held a much more important question was proposed: the removal of the College from Hudson to Cleveland (*23*). This question threw into the background all other matters for the next two years. A period of hesitation ensued; many students left the institution and there was general uncertainty. There is scarcely any room to doubt that the unrest of the college community over the removal, and the confusion of the actual transfer, drove out of mind President Andrews' petition and accounts for the neglect of action. No more business meetings of *Alpha* were held until June 24, 1885. Even election of new members was omitted. At the meeting in 1885 the members of the above-mentioned committee were not present and there is no reference then or at any subsequent meeting of Denison's request.

We are indebted for these facts to Dr. F. C. Waite, Professor in Western Reserve University and Historian of *Alpha* Chapter. He has carefully looked over the records and come to this conclusion:

> By the wording of the resolution it appears to me that this committee on June 25, 1878, was given power to approve or disapprove of the application of Denison, but the turmoil of the discussion of removal of the school probably drove that small question out of the minds of the members. Since there is no report of this committee there is no evidence as to whether the committee approved or disapproved of the application of Denison.
>
> All of the men who participated in this are dead and there is no way that I know of to secure any further information on this point (*24*).

From the foregoing it seems as if one more effort by President Andrews in renewing the application to *Alpha* Chapter might have recalled the matter to the attention of the committee and secured favorable action. But President Andrews was called to the professorship of Homiletics at the Newton Theological Institution and left Denison in 1879. No one else pushed the application and the effort to secure a charter of Phi Beta Kappa was dropped.

No petition from Denison was made to the *Beta* (Kenyon) chapter. At least no mention is made of one in the minutes of that chapter.

It is a satisfaction to find that the president and faculty of Denison made earnest effort, even when the College was yet young, to secure the benefits of Phi Beta Kappa. It would have been a great distinction, if the attempt had succeeded. The wonder is, not that the petition failed, but that it gained the approval of Brown University in the East and Marietta College, one of the oldest and most respected colleges of the Middle West. Success would have brought well-deserved recognition to our College for its scholarly character. As it was, the prize was delayed for more than thirty years and came only after very strenuous efforts and at least one more disappointment.

The matter was delayed, but postponement was not failure. At this very time Francis W. Shepardson was a young student of Granville. From the Kenyon College *Annual* of 1876 he first

learned of the Phi Beta Kappa Society. His interest was aroused and he conceived the thought of establishing a branch of this honorary society in his own college. Later events were to place him in a position to render effective service in realizing his dream. After finishing his course at Denison he proceeded to Brown University for graduate study. His scholarship at Brown entitled him and gained for him the distinction of membership in this Society to which he aspired. In the course of time he became a leader in its counsels and used his influence in winning approval of Denison's second application for a chapter of this Fraternity. Dr. Shepardson was promoted to the position of Senator of the United Chapters in 1913, and to the Vice-Presidency from 1919 to 1928.

The success of the College in respect to this honor rested also upon another youth, Emory W. Hunt, who was growing up in western New York and preparing unknowingly for a leading part in Denison's history. Graduating from Rochester University in 1884 and from Crozer Theological Seminary in 1887, he became a member of the *Iota* Chapter (New York) of Phi Beta Kappa in 1887. He came to Ohio as pastor of the Ashland Avenue Baptist Church of Toledo. Very soon he became connected with Denison as a Trustee, then as chairman of the committee to raise endowment, and on the successful completion of this purpose, as tenth President, 1902–1913. With unusual powers of leadership he was able to achieve the advancement of Denison in many directions, not the least of which was the securing of a chapter of Phi Beta Kappa.

Chapter III

HOPE DEFERRED

A period of nearly thirty years intervened before the next serious effort to secure a charter was made. The year 1906 marked a bright era in the history of Denison. The College was then three quarters of a century old. The seventy-fifth anniversary of the founding was celebrated with special exercises at the annual Commencement of that year, in which reviews were given of the development of the institution along material and scholastic lines (*25*). These reviews were encouraging, showing that much progress had been made in all essential directions. This was true particularly of the past ten years, in which the institution was modernized and had become established as a growing and strategic center of learning.

Dr. Emory W. Hunt had been called to the presidency in 1902. With him was a faculty of thirty-four instructors, well qualified by aptitude and special training for their work, with degrees from the best American universities and some of them with experience in foreign universities. The curriculum had been expanded and strengthened in several departments. A professorship of History and Economics and another of Engineering were recent additions. Other departments had been separated and new ones formed out of them, with professors at their head. The Endowment Fund had risen to almost a million dollars. The buildings and other property increased the value of the University's resources to a million and a quarter dollars.

Several new buildings which had been added in the past few years gave a more modern and substantial look to the College. Barney Science Hall had been completely rebuilt and improved after the fire of 1905. Cleveland Hall, with its accommodations for physical education, and for the Young Men's Christian Association, was a recent acquisition. Stone Hall had been com-

pleted in this year of 1906. The Central Heating and Lighting Plant had been installed, affording for the first time modern facilities of heat and light for all the dormitories and classrooms.

The science departments were widely known through the special research of their members. *The Bulletin of the Scientific Laboratories* had exchanges of publications with many of the important American and European universities. A library of several thousand volumes had just been received from the distinguished geologist, Carl Grove Gilbert, in recognition of the research accomplishments of Denison's geological department.

The tuition fees remained at the nominal sum of forty dollars a year. Following the custom of many universities the year was divided into two semesters. The courses were arranged in groups, which were prescribed for students aiming at particular lines of work. The degrees of A.B., B.S., and Ph.B. were granted. The total enrollment of students reached the high point of 568, of whom 341 were in the college departments.

Dr. Hunt had hardly been settled as President before he initiated the movement to secure a charter of Phi Beta Kappa for Denison. On October 11, 1902, he addressed an inquiry to Dr. Oscar M. Voorhees, Secretary of the United Chapters, regarding the method of applying for this favor. Dr. Voorhees, in his reply, specified three points: an application signed by the Phi Beta Kappa men connected with the University, the endorsement of five existing chapters, and evidence of the worthy character of the institution. Dr. Hunt made application in a typewritten statement. The next step was to secure endorsement of existing chapters. Dr. Hunt turned to several Ohio chapters and to others in colleges with which Denison had more or less connection. It appears from letters on file that the request to these institutions was not at once successful, except in the case of the *Beta* of Illinois (University of Chicago) which gave its endorsement at the summer quarter meeting, July 21, 1903. Chapters are proverbially slow in acting on such requests. On December 29, 1903, Secretary Voorhees wrote to Dr. Hunt, reminding him that the time was short for completing his application. The Senate

met on March 4 of the next year at New York. Evidently Denison's petition was not completed, for it was not presented at that meeting. Perhaps it was just as well, for nineteen colleges were petitioning for charters at that time and action on several of them, including Ohio Wesleyan University and the University of Illinois, was deferred. The next meeting of the Senate at which applications for charters could be received was three years later, in 1907. This gave time to set forth Denison's case more fully and to gain favorable consideration of its request. Dr. Hunt went ahead with the work of preparing the application and of securing the proper endorsements. The steps in his campaign are fairly clear from the correspondence, which embraces numerous letters from Dr. Francis W. Shepardson, Dr. O. M. Voorhees, and others.

Denison's application to the Senate and the United Chapters for the meeting in 1907 was a type-written copy of the regular blank form, entitled: *The United Chapters of Phi Beta Kappa. Information Required of Institutions Petitioning for a Charter.* A copy is in the Chapter's files. The Society makes a searching inquiry into the conditions of an institution seeking entrance into its numbers, respecting its standing and its prospects for advancement. On these points Dr. Hunt had gathered adequate information, receiving perhaps the help of Professor W. H. Johnson in compiling the data.

The petition was endorsed by five chapters in the following institutions, secured within the triennium since the meeting in March, 1904:

University of Rochester, June 14, 1904.
Marietta College, June 14, 1906.
Ohio State University, January 22, 1907.
University of Chicago, February 6, 1907.
University of Cincinnati, February 20, 1907.

The endorsement, usually a formal expression, was very pleasantly stated in the resolution of the chapter at Ohio State University:

The *Ohio Epsilon* Chapter of Phi Beta Kappa cordially endorses Denison University as an institution in every way worthy of membership in the society of the Phi Beta Kappa.

As the time drew near for the meeting of the Senate, Dr. Hunt must have suffered some anxiety as to the endorsements. Occasionally nudged by Dr. F. W. Shepardson, he kept "plugging away," as he said, until the last required approval was received, according to the above date, about two weeks before the Senate met.

Secretary Voorhees wrote to Dr. Hunt on February 16, 1907, notifying him of the date of the Senate's meeting, scheduled for March 8, in New York City:

> Your application is not yet at hand, nor have you filed with me the required information. I have notification of endorsement from the Rochester and Ohio State Chapters, and trust you may receive the required number in time.

The reason for this delay in sending in the application was, doubtless, that he was waiting for the endorsement of the University of Cincinnati, that was given on February 20. Then all the papers were sent at once and were in the Secretary's hands. What happened to them? Unfortunately, the only Senator who was well acquainted with Denison's standing, President Charles F. Thwing of Western Reserve University, had to leave before the application was considered. No one was there to speak for Denison, and so the application was deferred.

Possibly the case was weakened by the fact that the petition was not on an official form but on a type-written copy. This assumption is, however, contradicted by the Secretary's statement. The absence of the regular form was an oversight on the Secretary's part which he explained in a report to Dr. Hunt on the Senate's action:

> If I failed to send you a blank when it was prepared the fault is mine. My intention was to send copies to all who had written me respecting charters and as the other applicants began to return them, I had no thought but that you had one and would fill it out at your convenience. As our correspondence has been rather irregular I was of the opinion that you had given over the attempt to secure a charter for the present. It is proper to say at this point that your application did not fail of recommendation on technical grounds, for the Senate accepted your letter as practically covering the ground required by the blank. The necessary absence of Dr. Thwing, who left the meeting before your application came up, left us without a member acquainted with Denison. Hence action was deferred. Dr. Thwing has since written in hearty commendation of your standing,

and I have suggested to him that he assist you in coming to a conclusion as to the best course to pursue (*26*).

It is apparent from the above that the petition was postponed because Denison had no advocate to press her claims. All but three of the Senators were from eastern states and unfortunately the only member who was acquainted at first hand with Denison was not present when the matter was decided. It was balm for the hurt, however, that Dr. Thwing commended so warmly our University. His commendation was in the following terms:

I infer that the failure to recommend Denison University for membership was a technical one. In this case I am sure President Hunt would be glad to make good the lack. In case, however, the failure did not rest upon a purely technical basis, I venture to express to you the belief that Denison ought to be recommended. The University represents a high type of scholarship. When one has said this, one needs say no more in respect to our duty (*27*).

Chapter IV

SUCCESS ACHIEVED

During the triennium before the next General Council of the United Chapters, Denison's progress was marked in all essentials characterizing an educational institution. Swasey Observatory was added to the plant; the campus was beautified by the construction of ornamental gateways and of concrete steps and walks leading to the Plaza. The Endowment Fund had risen to over one million dollars and a movement was started to raise another million for endowment, buildings and equipment (*28*). The business administration was more specially organized by the appointment of a full-time Treasurer. In the face of increased tuition fees the number of students steadily rose to the highest point thus far recorded. A spirit of courage and hopefulness pervaded all circles. The University was in a period of growth and expansion.

These conditions gave confidence to renew the petition of 1907, which had been merely deferred for more information, for a charter of Phi Beta Kappa. Dr. Hunt was advised that it would increase the chance of acceptance, if a local society was formed, consisting of faculty members who had gained honors in their secondary school courses and of students in the senior class who were most distinguished for scholarship. This society was probably never organized with a constitution and with officers. It was forgotten as soon as the Phi Beta Kappa chapter was established, and most of the members of the preliminary society became members of the new organization. Some repercussions have been heard in later years in the claims of certain members of this local society, that they were assured that they would become members of Phi Beta Kappa as soon as this Society was established. This was probably a misunderstanding, as no one would be authorized to give such assurance, especially before the terms and agreement of the national society were known.

President Hunt filled out the blank form, bringing the information up to date. The application of 1907 was still in the Secretary's hands. It was supported by two more college chapters, in addition to those reported in 1907; by Oberlin College, June 22, 1909, and Colgate University, 1910.[1]

The personal support of President C. F. Thwing, one of the Senators, was assured in a cordial letter to Dr. Hunt:

> I am planning to attend the meeting of the Senators in New York on March fourth. From what evidence I have, I see my way clear to vote in favor of our recommending the granting of a charter to Denison. It would be hard to conceive of any evidence which should come up to oblige me to alter this judgment, for Denison has always stood for a high type of scholarship, and I am sure it will always so stand as long as you and worthy successors are filling your noble office (*29*).

To supplement the dry statistics of the blank of information, Dr. Hunt, probably with the aid of Professors W. H. Johnson and R. S. Colwell, prepared a seven-page typewritten statement which is of sufficient importance to be amply quoted in this account. It was addressed to the Members of the Senate of the Phi Beta Kappa Fraternity.

After summarizing briefly the history of the institution and its general policy, it comments on the character of the courses:

> In determining the contents of courses, Denison has kept in mind the ideal of a broad cultural foundation, making no attempt to provide the type of training appropriate to schools distinctively technical or professional. While the demand for introduction of scientific studies into college education has been heeded in the provision of laboratories, equipment, and a force of instructors, in which Denison justly takes pride, yet the aim has been to keep instruction in the sciences within the field of fundamental principles, and not to follow up the technical applications of these principles in competition with institutions organized and equipped for that purpose. With such ends in view, we seek to control the principle of student election of studies by a system of well-defined groups, so drawn

[1] It must have hurt when the chapter at Brown University denied the request for endorsement on the ground of "distance between the two institutions and our consequent inability to obtain reliable information concerning standards of scholarship." It was almost as if a mother would not recognize her daughter. To offset this was the cordial statement of Dr. Faunce, President of Brown University, who wrote privately to a friend of Denison:—Personally, I should be very glad to see Phi Beta Kappa in Denison University, and will do what I can to bring it about.—Letter of January 12, 1909.

as to prevent an undue narrowing of intellectual interests on the one hand, or the incoherent scattering of the seeker after easy courses on the other. Candidates for the A.B. degree are required to present both Latin and Greek for entrance, and to pursue each of these languages at least two years in college. All science groups require the fundamental college courses in Mathematics, Physics, and Chemistry, in addition to the courses of the special scientific department to which the group belongs; and all groups whatever must contain Freshman Mathematics, two years' work in English, and a year's work in the department of Philosophy.

Eschewing self-praise as unbecoming in the present instance, it continues:

We can only state that on the general lines of policy already indicated it has always been the endeavor of the trustees and instructors of this institution to make its name stand for honest and thorough work. As one indication of our determination to maintain such a standing for the future it may be stated that the Faculty has adopted a resolution, to go into effect with the present Freshman class, that no degree will be conferred upon any applicant whose record shall not show a ranking of A or B in courses amounting to at least one half the entire number of semester hours in the four years of his undergraduate work. . . . And we may add that the desire to secure a chapter of Phi Beta Kappa in Denison arises from a strong conviction that the presence of the organization will be a material aid in maintaining high scholarly ideals.

Of course one of the best evidences of the character of a school must ever be the record of its graduates in after life. During the first half century of the existence of Denison, its classes were never large, and yet the number of its graduates who won honorable distinction beyond the narrower circle of their localities and acquaintance was not inconsiderable.

There follows a list of some of the notable graduates, including several college presidents and professors in large universities, others eminent in foreign missions, in the ministry, and in the professions of law and medicine, and some distinguished in politics and in literature.

In reference to the University's attitude towards graduate study the statement adds:

It has always been the policy of Denison to encourage its graduates to further study. Even the small classes of the first ten years sent graduates to at least three medical colleges, four schools of theology, and three law schools, including Harvard and Yale. Only two classes in the history of the college are not on positive record as having sent graduates to some professional school, and those two exceptions would probably be removed if complete records were accessible. Beginning with the 80's Denison has had frequent representation in foreign universities, including Leipzig, Berlin, Heidelberg, Tuebingen, Paris, Edinburgh, and perhaps others. In this country it has sent its graduates to Harvard, Yale,

Columbia, Cornell, Johns Hopkins, Brown, Chicago, Michigan, Pennsylvania, Northwestern, Illinois, Wisconsin, Cincinnati, California, New York University, Boston University, Stanford University, and Ohio State University, or, in other words, to a large majority of the institutions doing genuine university work in which Phi Beta Kappa is represented.

Our application has been endorsed by more than the required number of chapters and these endorsements are on file with your secretary.

Under these circumstances, our formal application has been duly filed, in the strong hope that a careful consideration of the facts will convince you that the honor of the Fraternity will be safe in the hands of Denison University.

The petition was signed by eight members of Phi Beta Kappa and by Professor W. H. Johnson with the statement that he was "not a member of the Society." The eight signers became charter members, whose names were engrossed on the charter; namely:

Richard S. Colwell
Emory W. Hunt
Augustine S. Carman
Edgar J. Goodspeed
C. Judson Herrick
William B. Owen
Francis W. Shepardson
Ernest D. Burton

It was presented to the Senate at its meeting in New York City on March 4, 1910. Fourteen senators out of twenty were present. Fourteen applications for charters from colleges all the way from Radcliffe in Cambridge, Massachusetts, to the University of Washington in Seattle were before the Senate (*30*).

Only three were chosen by the Senate to be recommended to the Council: Beloit, Denison, and Indiana University.

The acceptance was reported to President Hunt the next day by the Secretary as follows:

I take pleasure in informing you that your application for a Charter of Phi Beta Kappa was unanimously recommended by the Senate yesterday. You will receive further information in due time.

The "first battle," to use Dr. Shepardson's phrase, had been won. It was necessary now to look ahead to the Council of the United Chapters six months later and to plan to capture that stronghold.

The Tenth National Council, consisting of officers, senators, and chapter delegates, met in New York September 13 and 14,

1910. The business session was held in Earl Hall of Columbia University, with thirteen senators and 115 delegates from sixty chapters present. Dr. F. W. Shepardson represented *Beta* (University of Chicago) of Illinois (*31*).

Denison's petition, unanimously approved by the Senate, was granted. Thus the long struggle for recognition was victoriously ended. Soon the good news was flashed to President Hunt. Dr. Shepardson, who was as deeply concerned in the result as anyone, made haste to speed the message and then came to deliver it in person. He relates that on his way from the telegraph office he met a friend who congratulated him on the success just won for Denison. "I will tell you," said this friend, "I would vote for Denison for a chapter of the Ohio Phi Beta Kappa for one thing, if for no other, and that is, for the last twenty-five years, at least, every year almost, some one has been inspired at Granville to go out and take graduate work in some other institution. There must be something in the place that leads towards scholarship—and that is why I voted in favor of your chapter."

The news of the honor that had been bestowed upon Denison was well received in Granville. The students as well as faculty appreciated this distinction. *The Denisonian* of September 23, 1910, made it the subject of a leading article of a column and a half, commenting in appropriate words upon the event:

> The Triennial Council of the Phi Beta Kappa fraternity, which met in Earl Hall, at Columbia University, New York City, on Wednesday, September 14, 1910, granted a charter to Denison University. The new chapter will be known as the "Theta of Ohio" the system of nomenclature combining the Greek letter indicating the order of establishment with the name of the state in which the chapter is located. In Ohio there are chapters at Western Reserve, Marietta, Kenyon, Cincinnati, Ohio State University, Oberlin and Ohio Wesleyan. A chapter will also be instituted at Miami, probably in the same week with the formal recognition exercises at Granville.

Then follows an account of the founding of the Society and its gradual growth during a century and a quarter. Concluding:

> New chapters have been established by each of the Triennial Councils, so that about eighty are now on the list, these being the representative colleges and universities of the United States. In giving Denison a place among the schools

whose scholarship is recognized as of Phi Beta Kappa calibre, the oldest American college Greek letter society has paid the Granville institution a gratifying tribute. The petition of Denison was supported at the New York conclave by Francis W. Shepardson, '82, who has been working with President Hunt for several years to secure the coveted honor.

Elections to membership will be few each year, the choice being controlled by the faculty and only students of exceptionally high standing in the classroom finding a place. The privilege of wearing the golden key badge of Phi Beta Kappa ought to be sought with earnestness by the best and brainiest of Denison's sons and daughters.

Dr. Shepardson, stopping off on his way back to Chicago, spoke enthusiastically at the chapel assembly of Denison's recognition. Again we quote from *The Denisonian* of the same issue:

At the chapel services last Friday morning, Dr. F. W. Shepardson, Associate Professor of American History in Chicago University and a Denison alumnus of the Class of '82, gave the students an interesting talk with reference to the chapter of Phi Beta Kappa recently secured for Denison.

He spoke of the high esteem in which Denison was held among other schools on account of the quality of research work done here. He said that Denison now fills such a large place in educational work that he has ceased to explain where it is.

He was gratified at seeing this last boyish wish fulfilled and he believed that long ago the school deserved its chapter of this honorary fraternity.

Throughout, the address was filled with enthusiasm and pride in his *alma mater*.

Chapter V

THETA CHAPTER INSTALLED

The victory which crowned the efforts of so many years was regarded with quiet satisfaction by those who were concerned. Perhaps only a few appreciated what a great distinction had been conferred upon Denison. It was generally felt, however, that the new society upon our campus would be an encouragement to scholarship and excellence. That was the tenor of an editorial in *The Denisonian* of October 13, 1910, which began with these words:

> Now that we have a chapter of Phi Beta Kappa at Denison, there should be an increased stimulus in scholarship. Formerly there was no reward for excellence in the classroom, equal to that received for work on the athletic field. Membership in this honorary fraternity more than meets the need and the possession of its key means more to a graduate than a "D".

Plans began to be considered for the installation of the chapter in a formal, public, and impressive manner. During the fall arrangements were quietly made by the local members and the officers of the United Chapters for this public service. It was desired by all that Dr. Edwin A. Grosvenor of Amherst College, President of the United Chapters, should be present to confer the charter. The date in December that was first suggested was found to be impracticable and a later one was agreed upon, Wednesday, January 18, 1911. Dr. Grosvenor agreed to be present for the inauguration of the chapter, to deliver the charter and to make the main address. Of course President Hunt was the unanimous choice to receive the charter and to serve as the president of the new chapter. But before the time arrived the serious accident that occurred to Dr. Hunt caused a change in plan and threw a shadow over the whole affair. On December 20 he slipped on the icy pavement at the foot of the "Drive"

and was dangerously injured. Although the accident was not considered serious at first, his convalescence was so slow, that it was soon apparent that he would not be able to attend the installation and participate in the service. His enforced absence was one of those strokes of ill luck with which Fate often mocks human arrangements. Dr. Francis W. Shepardson was then appointed to act in his place. It was a most appropriate choice, for he and Dr. Hunt had coöperated in securing the charter. It was Dr. Grosvenor's remark, that "no one was more interested in securing a charter for Denison than Professor Shepardson or was more active in demonstrating its claims" (*32*).

In the meantime Secretary Voorhees was having the charter engrossed and made ready for presentation. It is on parchment, twenty-five by twenty inches in size, and is shown well in Figure 1.

As only two of the charter members, the President and Dr. R. S. Colwell, were resident in Granville, Dr. Hunt raised the question of associating some of the faculty with them in organizing the chapter.[1] Secretary Voorhees, to whom the inquiry was made, replied:

> It is customary at that time (at the time of the organization) to select some of the most eminent members of the faculty, and also of the graduates as associates in the organization. Those who accept and are present are very properly designated "Foundation Members", as the first meeting has from the first been designated the "Foundation meeting" (*33*).[2]

Dr. Hunt referred the nomination of such foundation members to Dr. F. W. Shepardson and the other charter members at Chicago, suggesting Professor W. H. Johnson, who "has been of such service in preparing the way for the chapter, and is himself

[1] Dr. Augustine S. Carman, one of the eight charter members, had removed from Granville before this time.

[2] Dr. Voorhees' advice was based upon the statement in the Phi Beta Kappa General Catalogue relating to the duties and privileges of the charter members, which is as follows; "Upon them devolves the responsibility of making all preparations for the organization of the new chapter. They are privileged to select as associates a group of men from the faculty or alumni, or both, who are called Foundation members, from the term 'Foundation Meeting' that appears in the original charter. Those thus chosen become in reality either Honorary or Alumni members, with the added distinction of having part in the foundation of the chapter." *Phi Beta Kappa General Catalogue, 1776–1922.* xviii (1922).

The Phi Beta Kappa Fraternity.

CHARTER.

TO

Richard S. Colwell Augustine S. Carman C. Judson Herrick
Emory W. Hunt Edgar J. Goodspeed William B. Owen
Francis W. Shepardson and Ernest D. Burton

Fellow Members of the Phi Beta Kappa – Greeting:

Whereas, the National Council of the United Chapters of the Phi Beta Kappa Society has by resolution duly adopted on the fourteenth day of September 1910 decreed the establishment of a Chapter of the Phi Beta Kappa in connection with

Denison University at **Granville, Ohio**

and has directed the Senate by the President and Secretary to issue a charter in the name of the National Council: Now, therefore, by virtue of the aforesaid act of the Council and the authority delegated to us, we do hereby incorporate and establish you and such others as you may hereafter elect and associate with yourselves, in conformity to the law of the Phi Beta Kappa Society, into a separate and subordinate branch of said Society to be known and called the

Theta Chapter of the Phi Beta Kappa in the State of Ohio

hereby granting unto you and your successors all the powers, privileges and benefits thereunto appertaining, in as full and ample a measure as the members of the other and existing chapters enjoy; at the same time enjoining upon you in the organization and conduct of the new chapter, and as a condition upon which this charter is granted, strict compliance with the Constitution of the United Chapters and the Model Constitution herewith transmitted to you.

In Witness Whereof the said Senate has caused the seal of the United Chapters of the Phi Beta Kappa to be affixed hereto, with the signatures of the President and the Secretary.

Edwin A. Grosvenor
President

Oscar M. Voorhees
Secretary

of such intellectual rank," and tentatively Judson Harmon, '66, at that time Governor of Ohio (*34*).

Dr. Shepardson replied under date of December 9, 1910, adopting the nominations by Dr. Hunt and suggesting two other members, Professors George Fitch McKibben and Willis A. Chamberlin.

In the afternoon of January 11, 1911 the resident members met at the home of President Hunt. They associated with them the four alumni mentioned above, all of whom responded by their presence except Governor Judson Harmon, who was detained from appearing. At this first meeting of the chapter, the "Foundation meeting," as it was called by the Society from early times, these members were present to constitute the chapter: Dr. Emory W. Hunt, Dr. Richard S. Colwell, Professor William H. Johnson, Dr. George F. McKibben, Dr. Willis A. Chamberlin, and two members of other chapters who were "affiliated members": Dr. Charles J. Baldwin, *Eta* of New York (Colgate University) and Miss Edith Cox, *Alpha* of Illinois (Northwestern University), of the faculty of the Shepardson Conservatory of Music. Arrangements were made for the installation services to take place in the evening of January 18, 1911, in the Granville Baptist Church, to which everyone was invited. To emphasize the social side of the Society as well as the scholastic, Dr. and Mrs. Hunt invited all the members to the first banquet of the chapter at the President's home, preceding the public exercise. Guests of honor were Dr. Edwin A. Grosvenor, of Amherst College, who represented the United Chapters of Phi Beta Kappa in delivering the charter, and Dr. Francis W. Shepardson, who received the charter. This dinner was an auspicious beginning of the social entertainments which have marked the life of this Fraternity at Denison. The custom was established of holding a banquet each year at the time of the reception of new members and of the annual address.

As the hour for the public service approached, the members donned their academic dress and proceeded to the Church, to listen to the program appearing on the opposite page.

INSTALLATION THETA OF OHIO CHAPTER PHI BETA KAPPA

Professor Francis W. Shepardson, LL.D., Denison, '82, Brown, '83, presiding

Wednesday Evening, January 18, 1911, Seven O'Clock

Organ Prelude.....Miss Elizabeth Benedict
Invocation.....Dr. C. J. Baldwin, D.D., Colgate, '64
Vocal Solo.....Miss Edith Cox, Northwestern, '07
Presentation of Charter, by Professor Edwin A. Grosvenor, LL.D., Amherst, '67, President of the United Chapters of Phi Beta Kappa
Acceptance on the part of the Chapter, with address by Dr. Shepardson
Statement as to present and future membership in the Chapter
Professor Richard S. Colwell, D.D., Brown, '70
Song.....The Denison Glee Club
Address, "Ideals and Purposes of the Phi Beta Kappa Society"
President Grosvenor

This notable occasion marked a great achievement for Denison in the recognition of her standing among American colleges and in the world of learning. In *The Phi Beta Kappa Key*, official publication of the Society, an article by Professor Raymond W. Pence, descriptive of Denison and of this installation service, appeared in March, 1911, opening with this comment:

> The installation at Denison University of the *Theta Chapter* of Phi Beta Kappa in the State of Ohio on January 18, marks a turning point in the history of the institution. A fitting reward has come to the efforts covering many years to secure a recognition on the part of the educational world of the scholarship for which Denison stands. The attainment of this ambition should be of interest to all members of the Society (*35*).

Dr. Shepardson's address in receiving the charter is reported in the same article. Its introductory paragraph expresses the same thought:

> To me this is an occasion of great rejoicing. At last, by formal exercises, Denison has found its place in that distinguished list of American colleges which has had the stamp of high scholarship placed upon it. "This is the thing we long have sought," you know, "and mourned because we found it not," because some of us have felt for many years that we were entitled to this recognition here at Granville—that our ideals of scholarship and that the men of our student body and our faculty were such as justly to deserve recognition from the Phi Beta Kappa Society.

He quoted from the autobiography of his father, Dr. Daniel Shepardson, who there recorded that three things had always

appealed to him: one, a hill, "because it told of strength"; another, a tree, "because it told of beauty"; and the third, "an unfailing spring, because it told of power." Dr. Shepardson found all three things included in Denison:

> To me Granville is the hill, with its story of strength; the tree, with its story of beauty; the spring, with its tale of unfailing power. Sometimes one likes to get back to the fountainhead. One likes to go back to the source of strength; one likes to find where the machinery is, where the mechanism is that sets forces in motion. It certainly is the glory of Granville and of Denison that here in this village for eighty years now, four-score years, boys and girls have gathered to study that they might go out into this great commonwealth of Ohio and through all the Central States, to be leaders of light and of power, and the stream has flowed on and flowed on and flowed on, and we know that during all years to come out of Granville shall go forth strength (*36*).

The installation services were carried out as planned and made a favorable impression. The effect upon the student body was reflected by the account in *The Denisonian* in its issue of January 19, 1911:

> It is generally conceded that one of the most important events in the annals of Denison was the installation of the *Theta* of Ohio Chapter of Phi Beta Kappa last evening. Indeed, it might well be said that that event marks the beginning of a new era in Denison. One thing alone marred the beauty of the occasion. President Hunt was not able to attend. However, the presence of Professor Edwin A. Grosvenor, LL.D., President of the United Chapters of Phi Beta Kappa, and Professor Francis W. Shepardson, LL.D., of Chicago, did much to add to its significance.
>
> Dr. Shepardson presided at the meeting. He accepted on the part of the Chapter, the charter presented by President Grosvenor, and in a short address referred to an incident or two which showed the respect held for Denison, and the reason the charter was granted. His *alma mater* owes to him a great debt of gratitude for the services he has rendered in this regard.
>
> The main address of the evening was that by President Grosvenor on "Ideals and Purposes of the Phi Beta Kappa Society." President Grosvenor spoke in a scholarly manner of the history of the Society since its foundation in William and Mary College in 1776, until its reorganization and permanent establishment at Harvard in 1883. At present there are seventy-three institutions in the country with Phi Beta Kappa chapters, and about fifteen thousand members of the society. The ideals and purposes, perhaps, have never changed, but the Society has changed from oratorical to strictly scholastic, and its emblem, the key, is a badge recognized the world over as the emblem of high scholarship.

Chapter VI

THE FORMATIVE YEARS

The years from 1911 to 1918 may be called the period in which the young society at Denison was finding itself and cautiously adapting itself to the circumstances of our College. Pioneer work was necessary; first, to organize the chapter, then to draft the constitution and to formulate the policies, since the parent Society imposed no fixed customs regarding the local affairs.

Modesty was necessary in piloting the youthful Society through the early years, for it had to justify its existence in this college community, in which a group organized purely for scholarship was an innovation.

Criticism of the actions of the chapter was not lacking. To quiet unfair criticism the Society revealed as much as possible of its regulations for elections. It "showed its cards" to prove that its elections were reasonable and fair. By open meetings, by public addresses and other ways it sought to acquaint the public and especially the college community with its ideals.

It was fortunate for the Society that it enjoyed the leadership of men through these early years who were greatly respected. But by the year 1918 most of them were gone. Dr. R. S. Colwell was taken by death and Dr. E. W. Hunt, Professor W. H. Johnson, Dr. G. F. McKibben, Professor C. E. Goodell (an honorary member) had removed to other places. The World War had also intervened and disrupted college conditions in general. But the Society had established itself by this time. Its aims and activities were generally approved. Its procedures were fairly well determined. It had gained meanwhile many members both by election and by affiliation, among whom were capable leaders to carry forward the work so well planned by their predecessors. Henceforth it was destined to enjoy smoother sailing; the days of uncertainty were over.

Let us now resume the record from the time of the chapter's installation. A period of quiet for over two months followed the public service. President Hunt was away to recuperate and no effort was made for further advancement.

On March 30th, 1911, President Hunt having returned, a meeting was held at his home, at which steps were taken for the organization of the chapter. Dr. Hunt, who had accomplished by his persistent efforts the recognition of Denison by the Phi Beta Kappa, was unanimously elected President of the chapter, Dr. R. S. Colwell, Vice-President, and Willis A. Chamberlin, Secretary-Treasurer. The next most important items of business comprised the selection of members, both alumni and active, and the drafting of a constitution.

As it is customary in other chapters of the Fraternity to choose a few members from the faculty, this was the first step taken in electing new members. Under the provision, made in this particular case, of a unanimous vote, Professor Charles E. Goodell and Associate-Professor Anna B. Peckham were chosen from the faculty as honorary members.

Many alumni were eligible for election, who would undoubtedly have been elected as active members, if the chapter had been in existence during their college days. It is the usual practice to elect such graduates to membership, in completing the organization of a new chapter. No nominations were made at this meeting, but a committee consisting of Professor W. H. Johnson and Professor G. F. McKibben was appointed to present a list of alumni previous to 1890 for nomination to membership at a future meeting.

A generous number of active members from the senior and junior classes was agreed upon; not to exceed twelve from the former and five from the latter, these to be chosen "in the same proportion (in the nearest even number) of men and women as appears in the class itself." Thus did the new chapter seek to safeguard the balance between men and women in the membership. No such provision was made in the constitution and fortunately there has not been a marked disproportion of either sex. Both men and women have appreciated and have shared in appropriate numbers in such honors.

Professors W. H. Johnson, G. F. McKibben and W. A. Chamberlin were appointed a committee to draw up a constitution. The committee reported almost a year later, on March 13th, 1912.

On April 21 of the same year another meeting was called by President Hunt to consider the special business of electing alumni members, nominated by the committee mentioned above, and active members from the senior and junior classes.

On the nomination of the committee thirty-three alumni from 1850 to 1889 were elected to membership. Among them was one woman, Mrs. Grace Lyon Seasholes, '89, who was the only alumna up to that time.[1]

As the university records of students' scholarship were more accurate after 1889, the nomination of alumni for membership from the classes from 1890 to 1910 was an easier task. A list of eligibles was made from those having highest scholarship in the respective classes, care being taken not to elect too large a proportion of the class. Nominations having been made in the meeting of May 2, called by Vice-President R. S. Colwell, in the absence of President Hunt, alumni were elected on the basis of scholastic standing. Ninety-two alumni were elected at this meeting, including thirty-five women. To indicate how entirely the standard of scholarship was accepted for eligibility, it is interesting to note that one Negro graduate was elected at this time. At a meeting the next year, one more alumna from the class of 1906, whose name had been inadvertently omitted, was elected, making ninety-three alumni to be elected from the graduates of these two decades. Only one or two failed to respond to the invitation to join the Chapter, and one of them joined subsequently.

In the selection of these alumni it is shown that the Chapter proceeded with great care. A committee on nominations went over the list of graduates deliberately and acted as far as possible on merit, without prejudice. Their list was then, after a considerable time, presented before the Chapter and election was made. Some few graduates of genuine distinction and merit

[1] For the names *cf. Denison University Bulletin; Phi Beta Kappa, Theta of Ohio,* 1914.

were omitted from the nominations, but this was a mistake of judgment and not of intention. Twenty years later, in the Centennial year of the College, some of the alumni from 1870 to 1890 who were manifestly eligible, were elected to membership and thus the Chapter attempted to reward those who might well have been recognized at the earlier elections.

In the election of active members from the senior and junior classes, scholarship combined with moral character has always been the qualification. Pressure has sometimes been made to include popularity and distinction in other fields than pure scholarship, but the arguments in favor of something else than scholastic standing have always failed to persuade the Chapter to any other course than what has been accepted from the first. It has been emphasized again and again, especially in the early elections, that this is a Society to recognize scholarship and that scholarship is the only requisite, aside from moral character. The customary method of nomination is by the presentation of the list of students of highest standing in the class, made from the Registrar's records, and the Chapter proceeds to consider each name, beginning with the highest and so on until the limit of eligibility is reached.

Reception of New Members

New members were at first received into *Theta* Chapter without any formal initiation. They were publicly announced by name and were welcomed later at a meeting of the Chapter. It was soon thought, however, that more significance should mark this occasion. Accordingly a simple ceremony was devised of inducting the initiates into the Society at a public service and conformable to the ritual.

An important innovation was effected in the spring of 1921, when a whole chapel period was used for the recognition of new members. The Secretary read the names of the newly elected members and the President of the Chapter made an appropriate address in their honor. This service was held in the Baptist

Church, which was used in those years for the chapel assemblies. Swasey Chapel was first used for this purpose on March 14, 1927, the address being given by President Bunyan Spencer.

A more formal and impressive initiation of new members was inaugurated in 1929. The ceremony was extended and followed substantially the order recommended in the new ritual. The service was held in the auditorium of the Presbyterian Church on April 17 in the presence of the active members and preceding the annual banquet and address. The initiates were inducted into the Society by the officers and others. They were apprised of the history and purposes of the organization and exhorted to be loyal to the principles of "friendship, morality and learning." In token of their acceptance of responsibility as members they signed the Constitution and were then decorated with the golden key as mark of full membership. The service was dignified and impressive. It is seen to be appropriate for this Society and has been continued in the following years. A slight modification has been sometimes followed in holding these ceremonies on a separate evening and at the home of the President, lending a more social aspect to the service.

During the years our Chapter has received many accessions of affiliated members, especially from those who have joined the faculty. These members of Phi Beta Kappa from other colleges have been taken into membership of *Theta* Chapter automatically, receiving the rights and privileges as active members. No ceremony attended their entrance. As this did not seem quite sufficient to mark the importance of the occasion, a committee to devise a more significant reception of affiliated members reported a plan which has been used since 1934 with good success. These members come usually to the autumn meeting, where they are introduced by the President by name and with some account of their standing in Phi Beta Kappa and of their scholastic attainments. Then they hear a brief report of the history and ideals of *Theta* Chapter, that they may not enter the Chapter unacquainted with its policies. A social tone is given to the occasion, which is a marked event in the Chapter's calendar.

Honorary Members

According to custom in other chapters, *Theta* has occasionally extended its membership to persons of distinguished scholarship, who were not graduates of Denison. But it has been chary of granting this honor, reserving it as an especial distinction of a few. At the founding of the chapter it was deemed desirable to enlist two members of the faculty outside of the alumni of Denison. Charles L. Goodell, Professor of History and Political Science, and Anna B. Peckham, Associate Professor of Mathematics, were chosen for this honor. Within the next year Charles Woodyard, Instructor of Mathematics, was elected to honorary membership.

Dr. Ambrose Swasey, whose fame as a scientist is nation-wide, was elected to membership in 1924 and was invested with the golden key, as narrated elsewhere (p. 50).

Dr. Avery A. Shaw, well-known as a minister and executive throughout America, President of Denison University since 1927, received this honor by unanimous election on May 22, 1928.

Mrs. Dora Howland Case, a graduate of the Young Ladies Institute of 1875 and a woman of superior ability who had been actively identified for more than half a century with the interests of Denison and of Granville, was elected an honorary member of *Theta* at the autumn meeting of 1931. A unique feature of her initiation was the induction into membership at the same time of her grandson, Robert Edwards.

Theta recognizes with pleasure the presence in our faculty of six members of Sigma Xi, honorary scientific society. There is hearty coöperation between the members of these two groups in supporting scholarly activities at Denison. Some of *Theta's* members are also associated with the other body. Members of Sigma Xi are often guests at the Phi Beta Kappa banquets and completely harmonious relations exist between the two fraternities. The six members of Sigma Xi in the Denison faculty at present (1937) are as follows: W. C. Ebaugh, Professor of Chemistry; B. D. Greenshields, Professor of Engineering Science;

A. W. Lindsey, Professor of Zoology; L. E. Smith, Professor of Physics; F. B. Wiley, Professor of Mathematics; F. J. Wright, Professor of Geology.

Initiation Banquets

As noted elsewhere in this account, a banquet was served at the home of President and Mrs. Emory W. Hunt at the inauguration of the chapter on January 18, 1911. In the succeeding years the annual meeting was held near commencement time, when the program of events is too crowded for a formal banquet. These meetings were customarily held at the home of the President (Dr. R. S. Colwell) and social features were added to the business transactions by a welcome to the new members and the serving of light refreshments by the hostess. In the year 1916, however, a change is observed. On the evening of March 15 President and Mrs. Colwell entertained the local and affiliated members at dinner at their home from five to seven o'clock. Thirty-three guests were seated at the table and united in the enjoyable occasion. Toasts were called for by the President and responses made by Dr. Charles J. Baldwin (*Eta* of New York), Professor William H. Johnson and Dr. Clark W. Chamberlain. President and Mrs. Colwell repeated this enjoyable event the following year, when forty guests participated in their hospitality. Professor William Lyon Phelps, the orator for that year, was an honored guest and responded with others to a toast.

These happy occasions were sadly marred a year later by the death of the President, Dr. R. S. Colwell, on March 12, 1918. His passing bereft the Chapter of its last local charter member, who had had a marked and beneficent influence on the Chapter's policies during the formative years. He had served as President from 1912. No annual address was given this year. Effort was directed towards raising an endowment fund for the Phi Beta Kappa Fraternity. The Vice-president, Professor W. H. Johnson, acted as chairman during the remainder of the year and until his election as President at the annual meeting in June.

The custom of an annual banquet was resumed in the spring of 1919 under the presidency of Dr. Thomas A. Lewis. Dr.

Charles Judd of the University of Chicago was the honor guest in addition to the new members. Several toasts were presented before the gathering adjourned to Recital Hall to listen to the annual address.

From this time forward the banquet has been an annual event. It is given in compliment to the new members, who are the guests of the Chapter. The guests are ordinarily limited to the active members, living in Granville and vicinity, and their wives or husbands. A notable exception was made in the year 1924. On April 17 of that year a joint banquet of Phi Beta Kappa, the Faculty and Trustees of Denison University was held in the parlors of the Baptist Church, at which two hundred guests were seated at the tables. A memorable feature of this occasion was the presentation to Dr. Ambrose Swasey, who had been elected an honorary member of this chapter, of the golden key of membership. The presentation was made by Dr. Clark W. Chamberlain in behalf of Denison University.

The banquet signifies the one resplendent social event of the year for the Society. No effort is spared to make it an outstanding success. In recent years it has usually been held in the Granville Inn, with all the fitting features accompanying such an occasion. New members are given seats of honor and receive special attention. The orator of the year is also honored and usually responds to a brief toast. Other formal toasts are given by members. Since the practice has been established of having the annual address at the college chapel service in the forenoon, the whole evening is devoted to the banquet and reception. With the years it has developed from an informal home event to a formal function, emphasizing the standing of the Fraternity in the social life of the University.

Chapter VII

COOPERATION WITH THE GENERAL SOCIETY

The *Theta* of Ohio has made it a point of honor to be a worthy member of the United Chapters and to support the policies of the Fraternity. Its organization was carefully modeled after the precedents of older chapters and according to recommendations of general officers. It has participated readily in all the activities of the national body. Some measure of honor is reflected on this Chapter by the high place held by our charter member, Dr. Francis W. Shepardson, LL.D., in the counsels of the national organization. His membership in the Senate of the United Chapters since 1913 and his position as Vice-President is a matter of pride.

The review of twenty-five years reveals *Theta's* loyal coöperation with the Fraternity in all of its policies. It has had a part in the material progress and in promoting the spiritual aims of Phi Beta Kappa. Realizing that the life of the Fraternity depends upon the active participation of the chapters in the Triennial conventions, this Chapter resolved to send representatives to each Council. It has never yet failed to be represented. A list of our delegates to these Councils shows that the Chapter regarded it as important to be well represented, usually by the President and Secretary, at these gatherings.

Theta Chapter has borne its share in the financial support of the Fraternity. When the chance of securing a permanent office for the Secretary and headquarters of the Society in New York was offered, the Secretary, Dr. O. M. Voorhees, appealed to the individual chapters to raise definite quotas of the amount needed. He visited Granville to present this matter on December 17, 1917. After his report, the Chapter accepted unanimously the obligation to pay its share, if the whole amount was raised. In the sequel Dr. Voorhees wrote that the movement had apparently failed. The Society was not able to fulfill the provision.

A few years later the United Chapters decided to erect a memorial to Phi Beta Kappa. A building at the College of William and Mary, to be dedicated at the sesqui-centennial of the Society, was agreed upon. Accordingly a fund of $100,000 was raised. A committee of three was appointed by our Chapter to solicit subscriptions. One year later, March 12, 1924, the committee reported thirty-four pledges amounting to $448, of which sum nearly one-half was already paid. Although this amount is relatively small, it shows the good intentions and the loyal support of the young chapter. Two years later the same committee was asked to seek further subscriptions. Dr. Bunyan Spencer, President of the Chapter, was sent as *Theta's* delegate to the dedication of the Phi Beta Kappa Hall at William and Mary, November 27, 1926.

PHI SOCIETY

The organization of this society, comprising the students of highest scholastic standing in the freshman year, testifies to the zeal of *Theta* Chapter in stimulating scholarship. Probably no other action of this Chapter has attracted wider attention or gained greater approval. This freshman honor society was suggested by Dr. Eri Shumaker, '15, Associate Professor of English, and a member of *Theta*. Always a friend of the young, ardent, but inexperienced freshman, Dr. Shumaker conceived the idea of honoring those whose scholarship in the first year of the college course is outstanding, by joining them in a society. The Chapter took cognizance of his plan by appointing a committee, at the autumn meeting on October 22, 1926, to consider the advisability of organizing a Freshman Honor Society. The committee recommended the formation of the Phi Society under the auspices of the Phi Beta Kappa. Its name signified that it was to be a step towards membership in the parent organization. Eligibility requires the attainment of twenty-eight points in the first semester or fifty-six points in the whole year. *Theta* Chapter adopted this report and continued the committee to work out other details (*37*). Beginning with November, 1929, the custom was established of complimenting the new members of the Phi

Society with a banquet. On these occasions, which have grown in interest from year to year, the sophomores who have achieved in the preceding year the rank that entitles them to membership in Phi, are invited guests of the Phi Beta Kappa. An address is given by a speaker specially chosen or toasts are responded to. It is evident that Phi already fills a useful purpose in encouraging scholarship at the very time when the young students are forming their habits of study. Many of them are stimulated to continue the hard road of scholarship which brings them eventually into Phi Beta Kappa.

The success of Phi at Denison has been so marked, that it attracted attention in other institutions. It was not long before inquiries began to come, and branches of Phi were organized elsewhere. Dr. Shumaker was authorized to correspond with other chapters of Phi Beta Kappa about such branch organizations. Dr. Frank C. Ewart of Colgate University, alumnus member of *Theta*, was the first member of another faculty to recognize the value of a freshman scholarship society. He followed the example of the Denison Phi in organizing a society at Colgate in 1926, which is the first branch of the Denison vine. Branches have subsequently been founded at Ohio Wesleyan University, Western Reserve University, Cornell College, Iowa, and elsewhere.

The plan of Phi Society was presented to the Triennial Convention at Cincinnati in 1934, and the question was raised of recognizing it as a sort of junior Phi Beta Kappa. No decision was reached, but a generally favorable attitude was observed among the officers and delegates.

Phi has officially been recognized as an honor fraternity and was first listed as such in the 1935 edition of Baird's *Manual of American College Fraternities*. The following account is quoted from that standard authority on college fraternities:

"PHI SOCIETY"

(Freshman Scholarship Honor)

Phi Society was founded at Denison University, Granville, Ohio, in October, 1926, by the *Theta* of Ohio Chapter of Phi Beta Kappa, with the object of promoting scholarship among college freshmen. Announcement is made of new

members at the end of the college year, when recognition is also awarded upon the commencement program for excellent achievement in courses taken in the first two semesters of undergraduate work. The requirements for membership are the same as for membership in Phi Beta Kappa, except that they pertain to one year instead of four. There are neither local nor national officers. Each Phi society is organized and sponsored by a chapter of Phi Beta Kappa or by local faculty members of Phi Beta Kappa where there is no chapter of that honor society. Since the first society was established at Denison, other societies have been organized, at Colgate, 1926; Ohio Wesleyan, 1930; Western Reserve, 1930; Cornell College (Iowa), 1930; Rollins, 1935; John B. Stetson, 1935; Florida State College for Women, 1935. The badge is a gold charm or pin in the shape of the Greek letter "Phi". Both men and women students are eligible to membership.

THE PHI BETA KAPPA SCHOLARSHIP

Theta Chapter has been able to build up a gratifying fund of money which is invested in government securities and forms an endowment for the Society. A large part of the income from this source is required to secure a speaker of national reputation for the annual address. The rest and even a small part of the principal have been used as a scholarship award and in other ways to promote scholarly pursuits.

When the "depression" came and students were cramped in their resources, our Chapter saw a way of relieving the situation by using a part of this endowment as a scholarship fund. The matter was discussed in a meeting and was referred to a committee with power to act. Care was advised not to cut deeply into the fund, but to use the income. On the committee's recommendation a scholarship of $100 was offered for the year 1931–1932, on condition that it be granted to a senior who was a member of Phi Beta Kappa. The recipient for that year was Charles Welling. The scholarship was continued the next year when it was awarded to Charles Stoneking. It has not been granted since then, for fear of depleting the fund too much. But when the income justifies the expenditure, the Society will doubtless resume offering this scholarship. The terms of the grant make it a very high distinction for the recipient.

A loan fund has also been established, which is available according to conditions published in the *Annual Catalogue* of Denison University.

A small appropriation from this endowment fund has also been

voted as a contribution to the expenses of publishing the books of Dr. G. F. McKibben. It is in such useful ways that the Society expects to encourage scholarship directly at Denison.

Less obviously but also effectively its influence permeates the college atmosphere. At least once each year, at the announcement of new members, the attention of the whole student body is directed to the ideals of this Fraternity. It has urged the custom of publicly recognizing high scholastic attainments. On one occasion "Recognition Day" was observed, in October, 1923, when an address was made on the history and aims of Phi Beta Kappa and the names of all students were read who had won distinction in scholarship in the preceding year. A similar ceremony was observed at the sesqui-centennial of Phi Beta Kappa, December 5, 1926.

The annual address is presented as another means of benefiting the college community. As noted elsewhere in this account, such an address by some speaker of high reputation has been the custom from our foundation day.[1] *Theta* has been honored by the choice of several of its members to give this address at Denison and at similar occasions at other institutions. Of our members, those who have addressed us at such times are the following: Dr. R. S. Colwell, 1912; Dr. W. B. Owen, 1920; Dr. W. F. Shepardson, 1926; Dr. Frank Miller, 1931; Dr. E. J. Goodspeed, 1936.

It is a pleasure to note that President A. A. Shaw was chosen to give the Phi Beta Kappa address at Colgate University in 1934. Dr. L. R. Dean had a similar honor at Ohio Wesleyan University in 1934. Dr. Dean was chosen by the national fraternity to represent it with an address, in October, 1930, before the Coshocton High School, on the bimillenial celebration of Virgil.

[1] In Addendum II the names of orators and the subjects of the addresses are given.

REFERENCES

(1) CARMAN, A. S.: *Memorial Volume of Denison University, 1831–1906.* 5 (1907).

(2) Preamble of charter granted to Brown University in 1764; quoted from Bronson, W. C. *History of Brown University, 1764–1914.* 500.

(3) SHEPARDSON, F. W.: *Denison University Centennial History.* 11 (1931).

(4) CARMAN, A. S.: *Memorial Volume of Denison University, 1831–1906.* 17 (1907).

(5) VOORHEES, O. M.: *Phi Beta Kappa Key I,* No. 7, 20 (1912).

(6) *History of the Alpha Rhode Island Chapter of Phi Beta Kappa.*

(7) *Annual Report of the Trustees of the Granville Literary and Theological Institution,* October 6, 1832.

(8) *Report of John Pratt in behalf of the Faculty to the Trustees,* 1833.

(9) Letter of John Stevens, June 22, 1839, to Rev. John Pratt, Tecumseh, Michigan; also letter of July 11, 1839.

(10) Minutes of the Board of Trustees, August 14, 1833.

(11) Minutes of the Annual Meeting of the Ohio Baptist Education Society, 1837.

(12) SHEPARDSON, F. W.: Review of G. G. Wenzlaff's "Danforth Goes to College"; *The Granville Times,* September 10, 1936.

(13) Minutes of the Board of Trustees, May 17, 1832.

(14) CARMAN, A. S.: *Memorial Volume of Denison University, 1831–1906.* 17 (1907).

(15) SHEPARDSON, F. W.: *Denison University Centennial History.* 48 (1931).

(16) Letters of John Stevens to Rev. John Pratt, June 22, 1839 and July 11, 1839.

(17) Biographical sketch of Rev. John Stevens, D.D. in *The "Old Northwest" Genealogical Quarterly,* Granville Centennial Number, 279 (October, 1905).

(18) Scribner's *Dictionary of American Biography,* 1928, I.

(19) Article 6 of the "Greeting" of the Meeting *Alpha* of William and Mary College, Virginia. *Phi Beta Kappa Key, I,* No. 4, 17 (1911).

(20) Letter of Dr. O. M. Voorhees to Dr. F. W. Shepardson, February 7, 1934.

(21) Letter of Dean D. T. Schoonover to Dr. F. W. Shepardson, March 25, 1935.

(22) Copy of this resolution was enclosed by Dr. O. M. Voorhees in a letter to Dr. F. W. Shepardson, and forwarded by the latter to the present writer March 21, 1935.

(23) HAYDN, HIRAM COLLINS: *Western Reserve University; From Hudson to Cleveland,* 1878–1890.

(24) Letter of Dr. F. C. Waite, Historian of *Alpha* Chapter of Ohio, Phi Beta Kappa, February 18, 1937.

(25) CARMAN, A. S.: *Memorial Volume of Denison University, 1831–1906.* (1907).

(26) Letter of Secretary O. M. Voorhees to Dr. E. W. Hunt, April 12, 1907.

(27) Letter of President Charles F. Thwing to Dr. O. M. Voorhees, April 1, 1907.

(28) SHEPARDSON, F. W.: *Denison University Centennial History.* 254 (1931).
(29) Letter of Dr. C. F. Thwing to Dr. E. W. Hunt, February 12, 1910.
(30) *Phi Beta Kappa Publications*, New Series, No. 9.
(31) *Ibid.*, No. 11.
(32) Letter to President E. W. Hunt, November 8, 1910.
(33) Letter of Secretary O. M. Voorhees to President E. W. Hunt, November 22, 1910.
(34) Letter of Dr. E. W. Hunt to Dr. F. W. Shepardson, December 5, 1910.
(35) *The Phi Beta Kappa Key, I*, No. 3, 6–13 (1911).
(36) *Ibid.*, 12–13.
(37) *Annual Catalogue of Denison University for 1927–1928.*

ADDENDUM I

PHI BETA KAPPA ADDRESSES GIVEN AT DENISON

January 18, 1911

Public Installation

Dr. Edward A. Grosvenor, LL.D., President of the United Chapters
Ideals and Purposes of the Phi Beta Kappa Society.

June 12, 1912

Dr. Richard S. Colwell, President of *Theta* (Ohio) Chapter
The Value and Significance of the Phi Beta Kappa Society.

June 11, 1913

Dr. George E. Horr, President of Newton Theological Institution
The New Sense of Humanity.

May 29, 1914

Business and Social Meeting, no formal address

March 11, 1915

Dr. Paul Shorey, Professor at University of Chicago
The Scholar's Noblesse Oblige.

March 15, 1916

Dr. James McDonald, Editor of *The Toronto Globe*, was prevented by sickness from being present to deliver the annual address. A Business and Social Meeting was held at the home of Dr. and Mrs. Richard S. Colwell.

March 9, 1917

Dr. William Lyon Phelps, Professor at Yale University
Happiness and Culture.

December 17, 1917

(Extra Meeting)

Dr. Oscar M. Voorhees, Secretary of the United Chapters
Informal address.

June 4, 1918

No address

June 10, 1919

Annual Meeting, no address

April 23, 1920

Dr. Charles Judd, Professor at University of Chicago
What is Democratic in our Public Schools?

April 14, 1921

Dr. William B. Owen, Superintendent of Cook County (Illinois) Schools
Greater Efficiency in Public School Education.

May 3, 1922

Dr. Hamlin Garland, Author
American Writers Whom I have Known.

April 18, 1923

Dr. Arthur E. Bestor
Our Transition Period.

April 17, 1924

Dr. Charles F. Thwing, LL.D., President-Emeritus of Western Reserve University
Achievements of Members of this Society a Challenge to the Future.

April 22, 1925

Dr. Frank P. Gaines, Professor of English, Furman University
The Impulse of the South on American Literature.

April 14, 1926

Dr. Douglas W. Johnson, Professor at Columbia University
The Evolution of the Grand Canyon Region.

December 7, 1926

Sesqui-Centennial of the Founding of the Phi Beta Kappa

Dr. Francis W. Shepardson, Educator and Author, Vice-President of the United Chapters
A Union of Scholars.

May 2, 1927

Dr. Paul Shorey, Professor at the University of Chicago
Specialization and Culture—a Modern Problem.

March 8, 1928

Dr. William E. Dodd, Professor of History, University of Chicago
Robert E. Lee and Critical Moments in the Civil War.

April 17, 1929

Dr. Frederick B. Robinson, President of the College of the City of New York
New Horizons.

February 20, 1930

Meeting in Honor of Dr. Oscar M. Voorhees, Secretary

Dr. Voorhees spoke to Denison men at the Assembly

May 12, 1930

Dr. André Morize, Professor at Harvard University
The Meaning of Culture for Today.

April 15, 1931

Dr. Frank Justus Miller, Professor-Emeritus at University of Chicago
Four Years of Idealism.

April 20, 1932

Dr. Ernest Hatch Wilkins, President of Oberlin College
The Scholar and World Peace.

May 1, 1933

Dr. John Finley, Editor of *New York Times*
Vocation and Avocation.

April 24, 1934

Dr. Rufus M. Jones, Professor at Haverford College
Forces That Rebuild the World.

April 29, 1935

Dr. Carl Witke, Professor at The Ohio State University
The Crisis in Democracy.

April 24, 1936

Dr. Edgar J. Goodspeed, Professor at the University of Chicago
Adventures With Books.

Addendum II

OFFICERS OF THETA CHAPTER

President

Dr. E. W. Hunt	1911–1912
Dr. R. S. Colwell	1912–1918
Dr. W. H. Johnson	1918–1919
Dr. T. A. Lewis	1919–1920
Dr. W. A. Chamberlin	1920–1923
Dr. B. Spencer	1923–1927
Dr. F. G. Detweiler	1927–1929
Dr. L. R. Dean	1929–1932
Professor M. E. Stickney	1932–1935
Dr. Frank J. Wright	1935–

Vice President

Dr. R. S. Colwell	1911–1912
Dr. W. H. Johnson	1912–1918
Dr. T. A. Lewis	1918–1919
Dr. R. S. Tanner	1919–1921
Professor K. S. Eschman	1921–1922
Dr. F. G. Detweiler	1922–1923
Professor A. B. Peckham	1923–1926
Dr. F. G. Detweiler	1926–1927
Dr. F. J. Wright	1927–1929
Dr. W. A. Everhart	1929–1930
Professor A. B. Peckham	1930–1931
Professor M. E. Stickney	1931–1932
Professor A. B. Peckham	1932–1934
Dr. E. J. Shumaker	1934–1935
Dean Helen Olney	1935–

Secretary-Treasurer

Dr. W. A. Chamberlin	1911–1918
Dr. B. Spencer	1918–1923
Professor A. Odebrecht	1923–1930
Dr. W. A. Everhart	1930–

Historian

Dr. W. A. Chamberlin	1932–

Addendum III

DELEGATES OF THETA CHAPTER TO TRIENNIAL COUNCILS OF THE UNITED CHAPTERS

1913, September 9–10, New York, New York
Prof. A. Odebrecht
Prof. Willis A. Chamberlin
Mr. Otis Wilkinson (New York)

1916, September 12–13, Philadelphia, Pennsylvania
Dr. R. S. Colwell
Dr. W. A. Chamberlin
Dr. Frederick L. Hutson (Princeton)
Dr. Colwell was appointed a member of a committee to investigate the proportion of men and women in the Fraternity.

1919, September 9–10, Cambridge, Massachusetts
Dr. Bunyan Spencer

1922, September 12–13, Cleveland, Ohio
Dr. W. A. Chamberlin
Dr. B. Spencer
Dr. Millard Brelsford (Cleveland)

1925, September 8–9, New York, New York
Dr. Bunyan Spencer
Prof. A. Odebrecht
Rev. Harold Philips (New York)

1928, September 11–12, Delaware, Ohio
Prof. M. E. Stickney
Prof. W. A. Everhart
Prof. A. B. Peckham
Alternate, Prof. A. B. Skinner

1931, September 9–10, Providence, Rhode Island
Prof. A. B. Peckham
Dr. L. R. Dean
Dr. W. A. Everhart
(Only the first-named was able to be present)

1934, September 10–12, Cincinnati, Ohio
Prof. M. E. Stickney
Dr. W. A. Everhart
Dr. F. W. Shepardson

Addendum IV

THETA OF OHIO—PHI BETA KAPPA

CHARTER MEMBERS

Ernest D. Burton	(Beta of Illinois)
Augustine S. Carman	(Iota of New York)
Richard S. Colwell	(Alpha of Rhode Island)
Edgar J. Goodspeed	(Beta of Illinois)
Charles J. Herrick	(Delta of Ohio)
Emory W. Hunt	(Iota of New York)
William B. Owen	(Beta of Illinois)
Francis W. Shepardson	(Alpha of Rhode Island)

FOUNDATION MEMBERS

January 11, 1911

Willis Arden Chamberlin
Governor Judson Harmon† 1927
William H. Johnson† 1934
George Fitch McKibben† 1934

HONORARY MEMBERS

Charles E. Goodell†	Elected in 1911
Anna B. Peckham	Elected in 1911
J. B. Woodward	Elected in 1912
Roger P. McCutcheon	Elected in 1918
Ambrose Swasey	Elected in 1924
Douglas Johnson	Elected in 1926
Avery A. Shaw	Elected in 1928

ALUMNI MEMBERS

Class of 1850

Edward M. Downer, † 1914

Class of 1863

Thomas W. Powell, † 1922

Class of 1867

G. Moore Peters, † 1919

Class of 1868

Lewis E. Hicks, † 1922

Class of 1869

Jacob R. Davies, † 1933

Class of 1871

Edward E. Montgomery,† 1927

Class of 1872

William K. McKibben,† 1934
Benjamin Woodbury,† 1933

Class of 1873

Thomas J. Keating,† 1923
Charles J. Thompson,† 1914

Class of 1874

David E. Williams,† 1921

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† Deceased

Class of 1875

Dora Howland (Case),† 1936

Class of 1876

Vinton R. Shepard,† 1934

Class of 1878

Frank Rector,† 1933

Class of 1879

Osman C. Hooper
Frank J. Miller
Ira M. Price
Bunyan Spencer, † 1932

Class of 1880

Clarence F. Castle,† 1931

Class of 1881

Charles Henry Carey
Lorenzo D. Inskeep, † 1928

Class of 1882

Fred Dale Barker

Class of 1883

Jasper N. Field, † 1929

Class of 1884

William L. Malone, † 1929
Silas E. Price, † 1934

Class of 1885

John B. Childe, † 1935
Frank R. Morse, † 1914
George D. Shepardson, † 1926

Class of 1886

Benjamin F. McCann, † 1926

Class of 1887

August W. Foerste, † 1936
Robert J. Thresher

Class of 1888

Edward H. Castle, † 1929
George A. Dorsey, † 1931
Enoch J. Price

Class of 1889

William E. Castle
Grace Lyon (Seasholes), † 1924
James A. Smith, † 1925

Class of 1890

Gorman Jones, † 1936
Otis A. Wilkinson, † 1926
Edwin E. Wood

Class of 1892

Frank C. Ewart

Class of 1893

James F. Baldwin
Ernest J. Owen, † 1918
Charles B. White

Class of 1894

Clark W. Chamberlain
Edward P. Childs
Eva Gardner
Harriet Johnson, † 1932
James W. Kyle
Martha McMillen (Griffith)
Orlo J. Price
Leonard Riley

Class of 1895

William H. Huffman
John M. Lewis
George A. Moore †

Class of 1896

William T. Bawden
J. Carlton Bell
Elizabeth Ewart
J. Ernest Hutchins
Fred L. Hutson
Eleanor P. Lumley
Herman H. Severn

† Deceased.

Class of 1897

Helen Baldwin
Millard Brelsford
Jessie Husted (Chamberlain)
Wayland B. Clark, † 1924
Bert E. Lee
Lucille Powell

Class of 1898

John E. Chambers

Class of 1899

Grace Brumback (Henson)
William A. Colwell
Clara Davies
E. Howard Dudley
Cary L. Kelly
Edward E. Purinton

Class of 1900

W. Porter Beck
Clyde G. Conley
Frank C. Kreager
Jean McIntosh
Laura B. Moore
William J. Trimble, † 1920

Class of 1901

Platt R. Lawton
Oscar F. Moore

Class of 1902

Lewis H. Beall
Blanche D. Beattie
Fred Browne
Etta M. Crilly
Mary Mead (Renwick)
W. Dwight Sample, † 1935
Warner W. Stockberger
Dora Zimmerman

Class of 1903

Rachel H. Colwell
V. Ernest Field
David W. Guthrie, † 1927
Elmer M. Jones
Warren H. Roberts
Daisy Shambaugh (Gorham), † 1913

Class of 1904

Janet R. Jones
William E. Wickenden
Lilian A. Wyly (Champlin)

Class of 1905

Alma Blaisdell (Skinner)
Elsie Husted (Cotter)
Roger M. Jones †
Justin W. Nixon
Charles C. Patterson, † 1935
Myra C. Pellens
Marjorie Williams

Class of 1906

Gordon C. Beck
Anna Beattie
Clarice Carroll, † 1915
William A. Evans
Mary E. Ferguson (Legler)
Mary Hunt
Don C. Kite
Paul S. McKibben
August Odebrecht
Robert W. Sullivan, † 1919
Edna Thornton (Lake)
William B. Wright
Amy Zimmerman

Class of 1907

Dan S. Dye
Laura Beitler (Markle)
William G. Spencer
Ida Wickenden (Nixon)

Class of 1908

Irene Conley
Raymond C. Ditto
Lottie Grandstaff (Lloyd)
Theodore S. Johnson
Fred R. McArthur, † 1934

Class of 1909

Ruth Carlin (Landham)
Alva C. Early
Alva R. Edwards
Mildred Hunt

† Deceased.

Clarence Keyser
Kirtley F. Mather
Minnie Shaffer

Class of 1910

Faye Loring Cleveland
Bertha Lois Crilly
Albert Watson Davison
Robert Conant Dunn
Laura Elizabeth Hosick
Helen Kendrick Hunt
Betty Albertina Jones (Willett)
Sue Theobald (Miller)
Marie Porter (Mather)
Thurman Fred Sowers

Faculty

H. Rhodes Hundley (M. A. 1910), † 1934

MEMBERS IN COURSE

Class of 1911

Newton H. Carman
Adelbert B. Conley
Joseph S. Corey, † 1912
Karl H. Eschman
Clara D. Fifield (Jencks)
Hugh Clarence Gillespie
Homer D. Holler
Rachel Bernice Jones (Ramsay)
Ellsworth Boutelle Lowe
Leslie Bates Moss
Irma Marie Sargent (Waybright)
Letha Christina Tannehill

Class of 1912

Frederick M. Derwacter, elected in 1911
Karl W. Frasch, elected in 1911
Julia Sarah Moore (Webb), elected in 1911
Manly H. Shipley, elected in 1911
Florence Edna Wilson, elected in 1911
Katharine Courtney
Charles E. Davis
Ethel Deming (Hopp)
Helen Hultman
Max Norpell
Meta Stevens
Dexter J. Tight
Jane Williams

Class of 1913

Laura Prouty, elected in 1912; † 1914
Edith Southall (Fleener), elected in 1912
Raymond R. Weaver, elected in 1912
Karl R. Babb
Bess Bennett
George F. Finnie
Marguerite McNutt (Harrington)
Raymond C. Moore
Julia Seagrave (Patterson), † 1917
Richard W. Watkins

Class of 1914

Harriet Hunt (Richards), elected in 1913
Rachel Seagrave, elected in 1913
Mildred Gaynelle Bailey, † 1922
Edith Letitia Brown
Aden A. Grubb, † 1932
Joseph F. Haskins
Marjorie Lea McCutcheon (Sears)
Ruth Esther Rockwood
Harry Julius Schulman
Robert R. Weber
Ardon Kirk Wheeler
Lora S. Wright (Wilson)

Class of 1915

Clarence L. Fox, elected in 1914
Homer Adkins
Helen Gilmore (Crawford)
Randolph Rector, † 1930
Abigail Rowley
Eri J. Shumaker
Irene Tulloss

Class of 1916

Nellie Ballou, elected in 1915
Imogene Hamblen (Toy), elected in 1915; † 1930
A. Lowell Johnson, elected in 1915; † 1926
Clyde S. Adams

† Deceased.

Helen Olney
Harry M. Wood

Class of 1917

Grace Sinsabaugh (Smith), elected in 1916
Marie Tilbe (Blashill), elected in 1916
Spencer G. Weber, elected in 1916
Donald B. Atwell
James W. Ballard
James MacPherson
Grace R. Seagrave
Sara Taylor (Woodyard)
Louise Williams (Wright)

Class of 1918

Lucile Tilbe, elected in 1917
Grace Jefferson (Bodenweber), elected in 1917
Alfred J. Johnson, elected in 1917
Stanley Stephens Bash
Evangeline Beers (Jayne)
Marjorie Pickard Benoy
Frederick G. Detweiler
Ethel Garland
Amy Montgomery
Mary Adele Rowley
Edna Clare Shumaker

Class of 1919

Charles Theodore Bumer, elected in 1918
William A. Forbes
Harold C. Phillips
Mary E. Stewart
John H. Sutton
Stanley A. Willer
Eva Wilson (Houser)

Class of 1920

Mary Jardine, elected in 1919
David E. Owen, elected in 1919
Ava Ballou
Arthur T. Bawden
Robert Case
Laura Craytor (Boulton)
Burt Hodges
Richard H. Howe
Louise Hamblen (Owen)
Grace Moody
Garnet Schiedt (Deem)
Leslie B. Tribolet
Esther M. Weaver
Charles Langdon White
Owen N. Price (Class of 1918)
George W. Hazlett (Class of 1918)

Class of 1921

Louise G. Brecht, elected in 1920
David O. Voss, elected in 1920
Earl F. Adams
Theodore F. Adams
M. Forest Ashbrook
Helen Gholson
Irma G. Jones (Overstreet)
Herschel B. Lemon
Ruby Marion Robinson (Palmer)
Alva M. Shumaker
Helen Lenore Shumaker

Class of 1922

Carey Croneis, elected in 1921
Donald R. Fitch
Eleanor Floyd
Frances Inness
August Jones
Ralph G. Lusk, † 1927
Jenness Ruhl (Peckham)
H. Craig Seasholes
Gwladys Spencer
Ray E. Schaad
Ruth Weisenbarger

Class of 1923

Burton Chandler, elected in 1922
Maude E. Gill, elected in 1922
Albert T. Helbing, elected in 1922
Loraine Caul (Olney)
Sara Crist
Roger A. Crane
Ruth G. Hendricks
Howard B. Jefferson
Clyde E. Keeler

† Deceased.

Class of 1924

Mary T. Alspach (Krueger), elected in 1923
Ernest C. Brelsford, elected in 1923
Elfreda Jessel (Lovell), elected in 1923
Miles S. Masters, elected in 1923
Martha E. Wooden, elected in 1923
Dorothy Breeze (Bartlett)
Wallace B. Heiser
Henry Kendrick Holt
William G. Mather
Ellis J. Powell
Milton Schiller
Melvina Summers (Keeler)
Edna B. Taylor
Thomas Treharne
Katherine Williams

Class of 1925

Helen Proctor, elected in 1924
Marian C. Rowe, elected in 1924
Jose V. Aguilar
Turpin E. Bannister
Margaret A. Chamberlain (Masters)
Alma I. Chambers
Albert R. Griffith
Margaret B. Hendricks
William Thomas Hundley
James L. Knapp
Katherine B. McMillan (Ford)
Gladys Lucille Smith
Ernest J. Stockum
Ruth Sunderland (Dinsmore)
Mary Dodge White
James Tsune-Chi-Yu

Class of 1926

Naomi B. Alspach, elected in 1925
Robert W. Englehart, elected in 1925
June Mann (Morgan), elected in 1925
Florence A. Smalley (Mickle), elected in 1925
George R. Stibitz, elected in 1925
Gerald S. Wellman, elected in 1925
Helen M. Boss
Dean Dalton Deeds
James Earps
Dorothy Fulmer
Irene Hosick (Wright)
Donald Leslie
Eleanor Macklin (Frederick)
Dorothy Moor (Lawrence)
Dorothy Nichols
Eleanor Reed (Shultis)
Doris Simpson
Marguerite Smith
Herbert Waters
Almon Wright

Class of 1927

Roberta White (Taylor), elected in 1926
Grace R. Cleveland (De Puy)
Roberta Davis
George M. Garrison
Ethel Gilchrist
Jean Gordon
Winifred Graves (Ransom)
Mary Margaret Hendricks (Ross)
Eurie Loughridge
Vera Alice Miller
James Nicholson
Katherine Silliman (Olsen)
Evelyn Stephens
Elizabeth Wilbur (Cressey)

Class of 1928

Mary Elizabeth Case (Amner), elected in 1927
Andre Odebrecht, elected in 1927
Robert Price, elected in 1927
Carroll Amos
Homer Asquith
Helen Brabrook
Josephine Deeds (Krause)
Elaine Hannay
Elizabeth Heald (Hawes)
Bernard O. Heston
Inez L. Hooper (Gelfer)
Sara Lou Howland (Willike)
Joe Howland
Janice Mann (Brown)
Mary A. Mehnert (Muller)
Ruth Imogene Michael
Dorothy Odell

Mildred Proctor
Hilda F. Smith
Marian Spencer (Rogers)
Kennerd Tibbitts
Anne Wright

Class of 1929

George D. Heaton, elected in 1928
George Howard, Jr., elected in 1928
William W. Osmer, elected in 1928
Grace Woodford, elected in 1928
Albert Read Bakeman
Charles Millard Brelsford
Miriam Agnes Hildreth
Thelma Elizabeth Miley
Ward S. Miller
George T. Oxley
Edith Margaret Page
Hugh Dicus Smith
Emily Spencer (Douglas)
Stephen D. Tuttle
Margaret Williams (Swanson)
Virginia S. Wilson (Meidinger)
Mark B. Winchester
Flavia Helen Wyeth

Class of 1930

C. Douglas Deeds, elected in 1929
Winthrop W. Dolan, elected in 1929
Ralph E. Pickett, elected in 1929
Richard B. Brandt
Eugenia Couden
Leonard A. Crain
John F. Drake
Martha Gillespie
Florence Hoffer
Robert J. Kelly
Helen McPhail
Margaret Montgomery (Moore)
Pauline Pitts
Antoinette Shaw

Class of 1931

Helen Williams, elected in 1930
Mary Bender
Edward Hall Broadhead
Elizabeth Chamberlain (Hudson)
Helen M. Detweiler
Russell S. Geil
Mary Margaret Handel
Elizabeth Martin Hatch (Osmer)
Doris Mabelle Morgester (Pickard)
Marjorie Frances Rapp
Edward Richards
Elizabeth Brownson Stanton
James Steinberger
Eugene Winchester
William Eugene Young

Class of 1932

Robert C. Edwards, elected in 1931
James W. Uebelhart, elected in 1931
Charles E. Welling, elected in 1931
Pearl Bergoon (Leedy)
Linda Rogers Davis (Glennan)
Margaret Lepper (Bryce)
Lillian Maurer

Class of 1933

Charles Stoneking, elected in 1932
Frances E. Bingham (Bigler)
Jean Dawson
William Gibson Dildine
Joseph W. Gabel
Wilma Louise Lawrence
Margaret D. Little (Potter)
Florence L. Obenland
Mildred Elizabeth Zimmer

Class of 1934

J. Ernest Jensen, elected in 1933
Virginia Harrison Smith, elected in 1933
L. Sherwood Blasdel
Agnes Frazier (Eschman)
Eva Rose Fitch
Howard H. Keech
Marion Moreland
Allen E. Murray
Marguerite Oxley
Martha Ann Shepardson
John C. Stevenson
Roberta Thompson
William E. Umbach

Class of 1935

Clinton H. Nichols, elected in 1934
Glenna Snapp, elected in 1934
Carlyn Ashley (Frederickson)
Richard W. Ashley
Muriel Detweiler
Frank Hollingsworth
Margaret Huston
Richard L. James
Kenneth L. Maxwell
Sally Menaul
Gladys Merchant (Brintnall)
John E. Olt
John D. Osmond
Hazel L. Phillips (Butterworth)
Robert B. Taylor
Elizabeth Thomas
Lela Thuma
Ellen Wadsworth
Harold Wiley

Class of 1936

Miriam Dickerson, elected in 1935
Dorothy Fuller, elected in 1935
Catherine E. Ball
John Howard Bigelow
Agnes Darrow
Harriett Herron (Babbs)
Louise Mittendorf
Virginia Lee Shepard
Charlotte Anne Talbott
Louise Wagner
Lucian C. Warren
A. Elwood Wells
Neva Elizabeth Whitmore
Mary Ellen Wooten

Class of 1937

Janet M. Chatten, elected in 1936
Shirley Fitch, elected in 1936
Donald W. Western, elected in 1936
Lois V. Baird
George W. Baker
Mary I. Brown
Helen M. Darrow
Frances Erb
Frederick T. Holden
Margaret Lander Hopkins
Philip S. Lawrence
William J. Taylor
Robert M. Thorsen

Class of 1938

Charles Robert Deeter, elected in 1937
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THE TUNGSTEN FILAMENT INCANDESCENT LAMP[1]

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INTRODUCTION

As a result of the fundamental investigations on electromagnetic induction by Faraday and by Henry about 1830, the way was paved for machines for producing electric current for certain definite voltages. During the next few decades much progress was made in producing dynamo-electric machines or dynamos, so that when Brush brought out his arc lamp in 1878 and Edison his carbon filament incandescent lamp about a year later, they were both able to design and build the generating machines to operate their lamps.

From the viewpoint of the electrical engineer, a lamp filament is a resistance of such value that it will consume a specified wattage and operate at such a temperature that the life will have a predetermined value when the filament is shorted across the given voltage. Selecting the wattage and voltage fixes both the current and the resistance of the filament, and these two, together with the method of mounting and operating the filament, and the physical characteristics of the material used for the filament, determine its length and diameter.

That a filament so specified and so operated gives light at an economical efficiency is a happy accident, and depends to a great extent upon how well the lamp engineer has done his part in selecting the material for the filament, and the method of mounting and operating it.

The problem of the lamp engineer for the past fifty years or more has been the conversion of electrical energy into light in the most efficient manner possible; he must get as much light as

[1] Incandescent Lamp Department, General Electric Co., Nela Park, Cleveland, Ohio.

possible for the power used, that is, as many lumens per watt as he can, together with a satisfactory source of light.

The satisfactoriness, *i.e.*, ease of operation and appearance, of a source of light is more important than is sometimes considered. It is safe to say that almost no one would use as a source for general lighting anything less pleasing from the standpoint of color and less simple to operate than the present incandescent lamp, even if it were a great deal more efficient. The operation of the modern incandescent lamp is so simple and it is so convenient to use that one often fails to think of its great convenience.

EDISON'S CONTRIBUTION

The problem that confronted Edison in developing a practical incandescent lamp was to find a filament material and a method of mounting it such that the resulting lamp would produce light at an efficiency of such value that with the convenience of its operation, it could compete with the existing flame sources.

Before Edison's successful solution of the problem many attempts had been made to make an electric incandescent lamp using some of the well known materials such as platinum and carbon for the filament, but the resulting lamps were unsatisfactory because they were too low in intensity, had too short a life, or were of too low a voltage. Edison, after trying many materials for the filament of his incandescent lamp, decided that carbon was the best he could find, and his big problem then was to get a filament of carbon with small enough diameter to make a successful lamp for the high voltage desired. Edison figured that a multiple-operated lamp was necessary and that a voltage of at least 100 must be used in order to keep the line losses from becoming excessive. Edison's contribution to the art of incandescent lamp making was a filament of carbon of such a diameter and length that it would consume only about 100 watts when placed directly across a 110 volt line and also give sufficient light for a life of 600 hours, to compete with existing flame sources. Edison's first filaments were made by carbonizing pieces of sewing thread.

EARLY INCANDESCENT LAMPS

After Edison had made his first successful incandescent lamp for high voltage, he did not stop his investigation but kept on looking for a better carbon for the filament; and many other workers attempted to improve the carbon filament and to find a better material than carbon for the filament. A process of squirting (*1*) the carbon filament from a paste was developed which gave much more uniform filaments than those obtained from carbonizing threads or strips of bamboo. Dr. Whitney (*2*) many years later developed a method of improving the quality of the carbon filament by a process of heat treatment. The result of all of these improvements was an increase in efficiency from about 5.5 watts per mean horizontal candle (1.8 lumens per watt) for Edison's early lamp to about 2.5 watts per mean horizontal candle (4.0 lumens per watt) for Whitney's treated carbon filament, the Gem lamp. The incandescent lamp with a carbon filament or a treated carbon filament held the field of general lighting for about twenty-seven years.

The Nernst glower, which consists of a mixture of some rare earth oxides, was the first real competitor of the carbon lamp, but it is doubtful if it ever could have been developed to a point where it would have been able to displace the carbon filament lamp. However, shortly after it was introduced, other substitutes were suggested which were even better than the Nernst glower. Tantalum and osmium were both used as filaments. These were found to be about twice as efficient as the old carbon lamp, but only about 20 per cent more efficient than the treated carbon filament which they were attempting to replace. None of these could compete with the metal tungsten when it was introduced as a lamp filament material. In Table 1 data on the efficiency of some of the early incandescent lamps are given.

In order to make a good lamp filament a substance must so radiate that a large percentage of its radiated energy is in the visible spectrum, and in addition it must be a material that can by some means be made into a filament strong enough to permit mounting and to stand up under the conditions of use. The data in Table 19 show that for a tungsten filament the size of

TABLE 1

Efficiencies of some early incandescent lamps of about 60 watt size

	LUMENS PER WATT	LIFE
Edison's early carbon lamp	1.8	600 hrs.
Treated carbon lamp	3.2	600
Gem lamp	4.0	600
Nernst glower	5.0	600
Tantalum lamp	4.9	900
Osmium lamp	4.9	
Tungsten lamp (1907)	7.8	1000

TABLE 2A†

Properties of tungsten

TEMPERATURE °K T	SPECTRAL EMISSIVITY $e_{0.655\mu}$	SPECTRAL EMISSIVITY $e_{0.467\mu}$	AVERAGE LUMINOUS EMISSIVITY e_v	TOTAL EMISSIVITY e_t	BRIGHTNESS TEMPERATURE $S_{0.655\mu}$	COLOR TEMPERATURE T_c	RADIATION TEMPERATURE T_R	RELATIVE LENGTHS AT DIFFERENT TEMPERATURES L/Lo	THERMAL CONDUCTIVITY, WATTS /CM., DEG. K	ATOMIC HEATS, CAL./G ATOM, DEG. Cp	THOMPSON EFFECT, MICROVOLTS DEGREE
300	.470	.505		.024				1.0000			
400	.468	.501		.034				1.0005			
500	.466	.498		.042				1.0010			
600	.464	.495		.052				1.0014			
700	.462	.492		.062				1.0018			
800	.460	.490		.074				1.0023			
900	.458	.488		.089				1.0028			
1000	.456	.486	.464	.105	966	1006	581	1.0032	.84*	6.20	
1100	.454	.484	.463	.120	1058	1108	659	1.0036	.87*	6.35	
1200	.452	.482	.462	.137	1149	1210	738	1.0041	.90*	6.50	
1300	.450	.480	.460	.155	1240	1312	819	1.0046	.93	6.65	
1400	.448	.478	.459	.173	1330	1414	905	1.0052	.96	6.80	
1500	.445	.476	.457	.191	1420	1517	991	1.0057	.99	6.95	
1600	.443	.475	.456	.206	1509	1619	1080	1.0063	1.02	7.10	
1700	.441	.473	.455	.221	1597	1722	1167	1.0069	1.04	7.25	
1800	.439	.472	.454	.235	1684	1825	1254	1.0075	1.07	7.40	−18
1900	.437	.470	.453	.247	1771	1933	1342	1.0081	1.09	7.55	−20
2000	.435	.469	.452	.258	1857	2044	1428	1.0088	1.11	7.70	−22
2100	.433	.467	.450	.268	1943	2151	1514	1.0094	1.13	7.85	−24
2200	.431	.466	.449	.277	2026	2261	1601	1.0101	1.15	8.00	−26
2300	.429	.464	.448	.285	2109	2371	1688	1.0108	1.17	8.15	−28
2400	.427	.463	.447	.293	2192	2479	1775	1.0116	1.19	8.30	−30
2500	.425	.462	.446	.300	2274	2584	1859	1.0124	1.21	8.45	
2600	.423	.460	.444	.308	2356	2690	1945	1.0132	1.23*		
2700	.421	.459	.443	.314	2437	2797	2031	1.0140	1.25*		
2800	.419	.458	.442	.320	2516	2905	2116	1.0149*	1.27*		
2900	.417	.456	.441	.328	2595	3013	2202	1.016*			
3000	.415	.455	.440	.333	2673	3121	2286	1.017*			

† Data given in this table apply to aged tungsten filaments.

* These values are extrapolated.

that for a 115-volt, 500-watt lamp, only about 15 per cent of its radiated energy is within the visible spectrum. Up to temperatures well beyond those attainable with any known substance,

TABLE 2B*

Properties of tungsten

TEMPERATURE °K T	RESISTIVITY (MICROHMS CM.) ρ†	$\frac{T}{\rho}\frac{d\rho}{dT}$	NORMAL BRIGHTNESS (CANDLES PER CM²) B_n	$\frac{T}{B}\frac{dB}{dT}$	TOTAL RADIATION INTENSITY (WATTS/CM²) η‡	$\frac{T}{\eta}\frac{d\eta}{dT}$	LUMINOUS EFFICIENCY, LUMENS PER WATT EFF.	$\frac{T}{(\text{EFF.})}\frac{d(\text{EFF.})}{dT}$	RATE OF VAPORIZATION, GRAMS PER CM²/SEC. v	$\frac{T}{v}\frac{dv}{dT}$
300	5.65	1.209			0.00110					
400	8.00	1.209			.00495					
500	10.48	1.209			.0150					
600	13.07	1.209			.0385					
700	15.75	1.209			.0850					
800	18.51	1.209			.1730	5.47				
900	12.35	1.209			.333	5.50				
1000	24.26	1.209			.600	5.51				
1100	27.23	1.209			1.01	5.53				
1200	30.26	1.195			1.63	5.53				
1300	33.29	1.195			2.54	5.52				
1400	36.37	1.195			3.82	5.48	0.09	11.8		
1500	39.50	1.195			5.54	5.41	0.20	10.8		
1600	42.67	1.195	0.94	15.2	7.74	5.31	0.40	10.0	3.7×10^{-20}	67
1700	45.88	1.195	2.30	14.4	10.58	5.18	0.71	9.3	1.92×10^{-18}	63
1800	49.12	1.195	5.15	13.7	14.15	5.02	1.16	8.7	6.22×10^{-17}	59
1900	52.40	1.195	10.40	13.0	18.45	4.89	1.88	8.1	1.41×10^{-15}	56
2000	55.71	1.195	20.00	12.3	23.65	4.80	2.78	7.5	2.32×10^{-14}	53
2100	59.05	1.195	35.9	11.7	29.85	4.73	3.95	6.9	2.91×10^{-13}	50
2200	62.42	1.195	61.0	11.2	37.20	4.68	5.47	6.4	2.90×10^{-12}	48
2300	65.82	1.195	100.1	10.8	45.70	4.64	7.25	6.0	2.34×10^{-11}	46
2400	69.25	1.195	156.0	10.3	55.70	4.61	9.37	5.6	1.58×10^{-10}	44
2500	72.71	1.195	234.0	9.9	67.2	4.59	11.67	5.3	9.18×10^{-10}	42
2600	76.20	1.195	345	9.6	80.6	4.57	14.28	5.0	4.64×10^{-9}	40
2700	79.71	1.195	495	9.2	95.6	4.56	17.26	4.7	2.06×10^{-8}	38
2800	83.25	1.195	690	8.9	112.5	4.55	20.43	4.4	8.28×10^{-8}	36
2900	86.81	1.195	950	8.6	132.5	4.54	23.80	4.1	2.99×10^{-7}	35
3000	90.40	1.195	1270	8.3	154.5	4.53	27.10	3.8	9.92×10^{-7}	34

* Data given in this table apply to well-aged tungsten.

† These values depend on the dimensions at room temperature.

‡ Surrounded by a black body at 0°K. $\sigma = 5.735$ watts cm² deg^{-4}.

the proportion of the energy radiated in the visible spectrum increases with an increase in the temperature, so a high operating temperature is desirable. Tungsten satisfies these conditions

the best of any substance known because it has a very low vapor pressure, which permits operation at very high temperatures, and because it radiates selectively in favor of the visible spectrum. Despite many statements to the contrary, no substance is known, either an element or a compound, that can be used as a filament that satisfies the radiating conditions for a life beyond a few hours as well as tungsten, and this does not take into consideration some of the other valuable properties of tungsten as a filament material. This point should be stressed: there is no substance known today that can be used as a lamp filament that is as efficient as tungsten for a converter of electrical energy into light—on the basis of a life beyond a few hours—and no reservations are made as to cost, difficulty of manufacture, or any other considerations.

TABLE 3

Tensile strength of tungsten

KIND OF MATERIAL	DIAMETER		TENSILE STRENGTH	
	Mils	Millimeters	lb. wt./in.^{2}	kg. wt./mm.^{2}
Sintered tungsten ingot	200 by 250		18,000	13
Swaged rod	216	5.49	50,600	36
Swaged rod	125	3.18	107,000	75
Swaged rod	80	2.03	176,000	124
Swaged rod	26	.660	215,000	151
Drawn wire	18	.457	264,000	186
Drawn wire	7.23	.184	340,000	239
Drawn wire	5.78	.147	366,000	257
Drawn wire	5.50	.139	378,000	266
Drawn wire	3.96	.101	483,000	340
Drawn wire	1.14	.029	590,000	415

CHARACTERISTICS OF TUNGSTEN

A number of the physical properties of tungsten (*3*) as well as some of its radiating characteristics are shown in Tables 2, 3, and 4. Some of these properties were unknown when it was first used as a filament and even then, though no method was known of using at least two of its properties (ductility and strength), no other metal or compound was able to compete with tungsten as a lamp filament. The outstanding properties that make

TABLE 4

Current I, in amperes and potential gradient dV/dl, in volts per centimeter for various-sized tungsten filaments at different temperatures*

TEMPERATURE, °K		RADIUS IN CM.											
		.001	.002	.003	.005	.008	.01	.015	.020	.030	.050	.080	.100
400	I	.00307	.00868	.0159	.0343	.0694	.0970	.178	.274	.504	1.09	2.20	3.07
	dV/dl	.00781	.00552	.00452	.00349	.00276	.00247	.00196	.00175	.00143	.00111	.000874	.000781
600	I	.00722	.0210	.0385	.0829	.168	.235	.431	.663	1.22	2.62	5.28	7.22
	dV/dl	.0300	.0218	.0178	.0145	.0109	.00976	.00796	.00690	.00507	.00436	.00344	.00300
800	I	.0136	.0385	.0707	.152	.308	.430	.791	1.22	2.24	4.81	9.74	13.6
	dV/dl	.0802	.0568	.0463	.0359	.0284	.0254	.0207	.0179	.0147	.0113	.00898	.00802
1000	I	.0221	.06260	.115	.247	.501	.700	1.29	1.98	3.64	7.82	15.8	22.1
	dV/dl	.171	.121	.0986	.0764	.0604	.0540	.0441	.0384	.0311	.0241	.0191	.0171
1200	I	.0327	.0925	.170	.366	.740	1.03	1.90	2.93	5.38	11.6	23.4	32.7
	dV/dl	.315	.223	.182	.141	.111	.0996	.0813	.0704	.0575	.0445	.0354	.0315
1400	I	.0457	.129	.237	.510	1.03	1.44	2.65	4.08	7.49	16.1	32.6	45.7
	dV/dl	.529	.373	.305	.236	.187	.167	.137	.118	.0964	.0747	.0590	.0529
1600	I	.0600	.170	.312	.671	1.36	1.90	3.48	5.36	9.86	21.2	42.9	60.0
	dV/dl	.815	.575	.470	.364	.288	.258	.210	.182	.149	.115	.0911	.0815
1800	I	.0756	.214	.393	.845	1.71	2.39	4.39	6.76	12.4	26.7	54.1	75.5
	dV/dl	1.18	.835	.682	.528	.418	.374	.305	.264	.216	.167	.132	.118
2000	I	.0928	.263	.482	1.04	2.10	2.94	5.39	8.30	15.3	32.8	66.4	92.8
	dV/dl	1.65	1.16	.950	.737	.582	.520	.425	.368	.300	.233	.200	.165
2100	I	1.00	.283	.520	1.12	2.27	3.17	5.82	8.96	16.5	35.4	71.6	100
	dV/dl	1.88	1.33	1.09	.842	.665	.595	.481	.421	.344	.265	.210	.188

2200	I	.109	.307	.565	1.22	2.46	3.44	6.31	9.70	17.9	38.4	77.7	109
	dV/dI	2.16	1.53	1.25	.966	.764	.683	.558	.482	.394	.305	.241	.216
2300	I	.117	.332	.610	1.31	2.65	3.71	6.81	10.5	19.3	41.5	83.9	117
	dV/dI	2.46	1.74	1.42	1.10	.869	.777	.650	.550	.449	.348	.275	.246
2400	I	.126	.357	.656	1.42	2.86	3.99	7.33	11.3	20.7	44.6	90.3	126
	dV/dI	2.78	1.97	1.61	1.25	.984	.880	.718	.622	.508	.393	.311	.278
2500	I	.135	.383	.703	1.51	3.06	4.28	7.86	12.1	22.2	47.8	96.8	135
	dV/dI	3.13	2.21	1.81	1.40	1.11	.991	.808	.700	.572	.443	.350	.313
2600	I	.145	.410	.752	1.62	3.28	4.58	8.41	13.0	23.8	51.2	104	145
	dV/dI	3.51	2.48	2.03	1.57	1.25	1.11	.906	.785	.641	.497	.393	.351
2700	I	.154	.436	.801	1.72	3.49	4.88	8.97	13.8	26.3	54.5	110	154
	dV/dI	3.91	2.77	2.26	1.75	1.38	1.24	1.01	.875	.714	.554	.438	.391
2800	I	.164	.463	.851	1.83	3.71	5.18	9.51	14.7	26.9	57.9	117	164
	dV/dI	4.34	3.07	2.51	1.94	1.53	1.37	1.12	.971	.793	.604	.486	.434
2900	I	.174	.493	.905	1.95	3.94	5.51	10.1	15.6	28.6	61.6	125	174
	dV/dI	4.81	3.40	2.78	2.16	1.70	1.52	1.24	1.08	.879	.680	.538	.481
3000	I	.184	.521	.956	2.06	4.16	5.82	10.7	16.5	30.2	65.1	132	184
	dV/dI	5.50	3.89	3.18	2.46	1.95	1.74	1.42	1.23	1.01	.778	.616	.550

Filament in vacuum radiating to surroundings at 293°K.
* Calculated Jan., 1937, by P. D. Cargill.

tungsten valuable for this special purpose are: (1) favorable radiating characteristics, (2) lower vapor pressure and high melting point, (3) high tensile strength, and (4) its ductility. It is also fortunate that there is a sufficient supply of the metal so that filaments are not excessive in cost.

How important the cost of the tungsten wire, which is very much cheaper than platinum wire, is in determining the lamp cost is shown by the small amount required for a filament—a

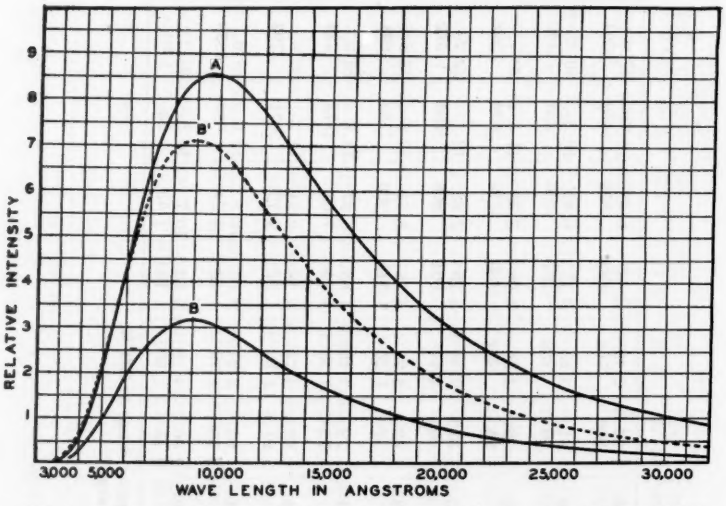

FIG. 1. Radiating characteristics of tungsten. Curve A—black body 3000°K, Curve B—tungsten 3000°K, Curve B′—tungsten equal black body in visible. Φ_W = 31.3 per cent Φ_{BB}, F_W = 43.5 per cent F_{BB}.

pound of tungsten is sufficient for 75,000 filaments for the 40-watt, 115-volt lamp and for about 1,000 filaments for the 500-watt, 115-volt lamp.

The curves in Figure 1 show the favorable radiating characteristics of tungsten. Curve A shows the spectral radiant intensity of a black body at a temperature of 3000°K. Curve B shows the corresponding radiant intensity for tungsten at the same temperature. Curves A and B show the radiant flux from one

square centimeter of area of the black body and of tungsten, and curve B′ is for tungsten also at 3000°K and for an area (2.27 cm^2) that will radiate as much light as one square centimeter of a black body at the same temperature. Curve B′ shows that for the same emission of light, at 3000°K, tungsten radiates only 76 per cent as much energy as the black body at this same temperature (relative area under curves A and B′).

DRAWN TUNGSTEN WIRE

When tungsten was first used as a filament, no one knew how to draw tungsten wire, so filaments had to be made by the squirting process. From a paste made of tungsten powder and a binder, wire was made which, by heat treating, could be made into a very fragile tungsten filament. A method of making tungsten wire of almost any diameter desired was discovered in a very extensive investigation by Dr. Coolidge (*4*) at the General Electric Research Laboratory at Schenectady. The discovery of the method of making ductile tungsten wire was a very important step in lamp making. It is hard to imagine how the present day lamp with all its exacting specifications could be made if drawn tungsten wire were not available. The use of drawn tungsten wire for the filaments enabled lamps to be made for a very definite current and voltage operation. Some of the incandescent lamps require filaments of very small diameter. The filament of the 40-watt, 115-volt gas-filled lamp is only about 1.3 mils (0.035 mm.) in diameter; and a 5-watt, 115-volt lamp requires a filament that is only about one-tenth the diameter of the average human hair; that is, the filament is only about 0.3 mil (.007 mm.) in diameter!

Curve A, Figure 2 shows the efficiency of tungsten as a light source as a function of its temperature. These data refer to the efficiency as a function of temperature of a filament mounted in a vacuum where the filament is long enough so that any losses due to heat conduction by the leads or supports may be neglected. Curve B of this same figure shows (as a function of the temperature) the efficiency of the black body as a light source.

The lamp engineer is constantly striving to find methods of manufacture that will enable him to make a lamp for the designed

life with a higher efficiency and at the same time to secure as uniform a product as possible. This desire to secure a uniform product has been largely responsible for the introduction of so many machine processes in lamp making. It can be safely said that not a single machine has been introduced in any of the processes of manufacture of lamps or lamp parts that has not resulted in both a better lamp and a more uniform product. Those in the lamp industry are of the opinion that the quality

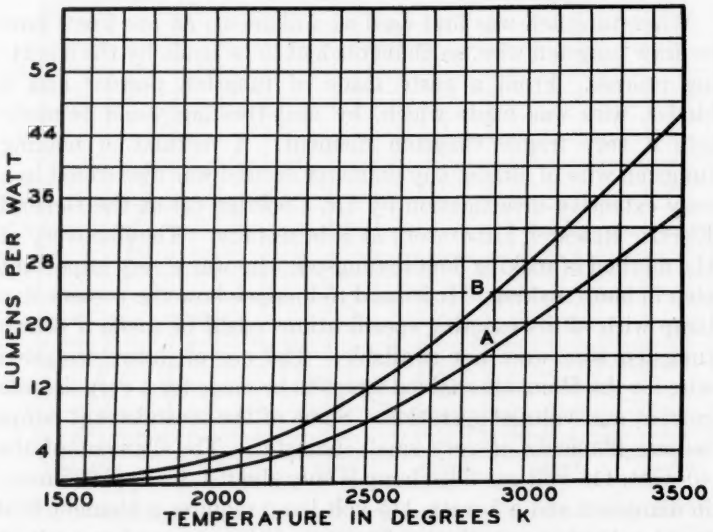

FIG. 2. Luminous efficiency of black body and tungsten as a function of temperature.

of no modern product is guarded more jealously than that of the incandescent lamp.

Since the life of the tungsten lamp is determined in general by the rate of evaporation of the filament, the lamp engineer is constantly searching for a method of reducing the effectiveness of the evaporation and of reducing the other losses of energy and light. Among the more serious losses that the engineer has to deal with are: (1) Heat conduction by the leads and supports.

(2) The IR drops in the leads. (3) The absorption of light by the bulb and the base of the lamp, and (4) The loss of light due to the blackening of the bulb caused by the evaporation of the filament. The IR drop in the leads is kept down by using leads of such size as to keep this loss a compromise with added cost due to the large lead. The loss due to the absorption of light by the base of the lamp is kept small by making the base with as little absorption for light as possible; thus while the base may intercept about one per cent of the light from the lamp, the light lost by this interception is much less than one per cent.

The reduction in the diameter of the filament due to the evaporation reduces the efficiency of the lamp, since a filament of smaller diameter operates at a lower temperature on constant voltage, and thus at a lower efficiency. If the diameter of the filament of an incandescent lamp were perfectly uniform at the start and was reduced uniformly by evaporation, it would never burn out but would be constantly reduced in temperature until it gave no light. The lamp bulb and the filament must be strong enough so that they will not be broken in the ordinary handling necessary in shipping and in use. Thus, the lamp engineer must study means of strengthening the bulb and the filament as new hazards of use develop. He has as his goal the making of the very best lamp that it is possible to manufacture for the particular service for which the lamp considered is intended. As an example, a rough service lamp is made which, while it is not as efficient in lumens per watt as the lamp of corresponding wattage that is used for general lighting, is much more satisfactory to use on the end of a long drop-cord.

GAS-FILLED LAMPS

The first major improvement in the efficiency of the tungsten lamp resulted from a successful attempt to reduce the rate of the evaporation of the filament so that it could be operated at a higher temperature and thus at a higher efficiency. Before tungsten had replaced carbon as a lamp filament, attempts were made to increase the operating temperature of the carbon filament and thus its efficiency by reducing the rate of evaporation

from the carbon filament. It was reasoned that if the carbon filament were surrounded by a high pressure of some inert gas, the rate of evaporation would be reduced to such an extent that it could be operated at a higher temperature, which would result in an increased efficiency and still maintain the same life. It was known, of course, that if the carbon filament could be operated at a higher temperature, the efficiency would be greatly increased. This attempt to operate (*5*) the carbon filament in an atmosphere of argon was made and it was found that while the carbon filament would operate at a much higher temperature for the one thousand hours life, it was, under these conditions, if anything, less efficient than the vacuum lamp because the losses due to the conduction and convection by the surrounding gas more than made up for any gain in efficiency due to the operation at a higher temperature. Langmuir (*6*) made a study of this problem and found that when a filament is operated in an atmosphere of an inert gas, it is surrounded by a more or less stationary sheath of the gas and that the percentage of the input energy that is lost by the gas is much less for filaments of larger diameter. He showed that these losses were markedly reduced by coiling the filament into a helix since then the gas sheath surrounded the entire coil and thus the losses depended upon the diameter and the overall length of the coil and not that of the wire. By this method a 500-watt gas-filled lamp was then made that was about 40 per cent more efficient than the corresponding vacuum lamp. As a result of Langmuir's work, the lamp engineer was given a great advantage—and also was given further difficulties to overcome.

The gas first used in these gas-filled lamps was nitrogen. It was early recognized that some of the inert gases would be more satisfactory for this purpose since their heat conductions are considerably less than that of nitrogen. Twenty-five years ago one would hardly have hoped that sufficient argon could be obtained at a price that would permit it to be used to fill the present-day gas-filled lamp. Again the lamp engineer worked out ways and means for obtaining the necessary argon, so that most of the present-day gas-filled lamps have an atmosphere

that is made up of about 80 per cent argon and the remainder nitrogen.

GAS LOSSES

The requirements of the gas used with respect to its purity and freedom from water vapor are very rigid. The reason for this is that some of the impurities that are naturally present react

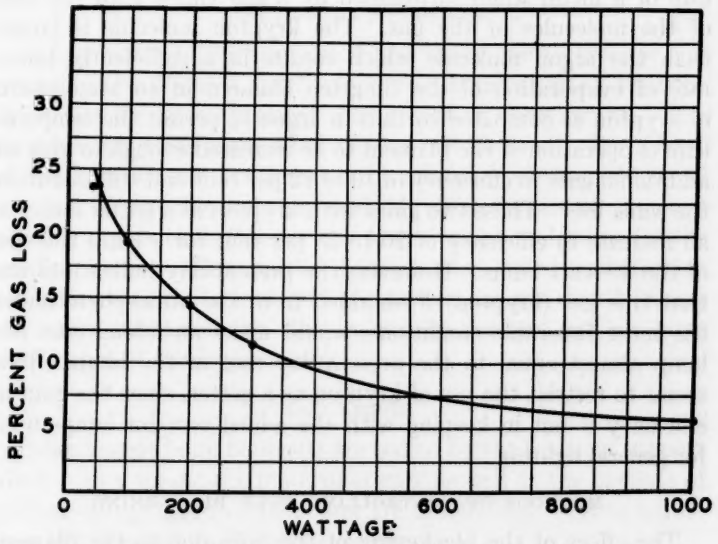

FIG. 3. Per cent gas loss as a function of the wattage of the lamp

with the tungsten filament and reduce its strength, and water vapor may even increase its rate of evaporation. How serious the gas loss is for small lamps is shown by the curve in Figure 3, which gives the per cent gas loss for different size lamps. Chemicals are sometimes used in the lamps to remove the last trace of harmful gases or water vapor.

KRYPTON AS A GETTER

An additional gain in efficiency of the gas filled tungsten lamp would be possible if the gas, krypton, could be obtained in

sufficient quantities and at a cost that would justify its use as the getter in the lamp. Any substance put in the bulb to improve the operation of the filament is called a "getter." Krypton has a lower heat conductivity than argon and for a 40-watt, 115-volt lamp, this would result in 10 to 15 per cent gain in efficiency, and an additional gain in efficiency is given by the Ludwig-Soret effect, which is, that the rate of evaporization of a metal when surrounded by a gas varies with the size of the molecules of the gas. The krypton molecule is larger than the argon molecule which results in a sufficiently lower rate of evaporation of the tungsten filament in an atmosphere of krypton as compared to that in argon to permit the temperature of operation of the filament to be increased enough to give an additional gain in efficiency of 10 to 12 per cent and still maintain the same life. These two gains with krypton as a getter indicate an increase in efficiency of 20 to 25 per cent for a lamp the size of the 40-watt lamp. However, the present-day indications are that this gas (krypton) if obtained from the atmosphere under the most favorable conditions, would make an added cost per lamp almost equal to the present-day cost of the lamp. This seems to restrict the use of krypton as a getter, since the gain in efficiency is not in keeping with the added cost for lamps used for general lighting.

METHODS OF CONTROLLING BULB BLACKENING

The effect of the blackening of the bulb due to the filament evaporation can be reduced considerably by putting in the bulb some coarse tungsten powder (*7*) and using this at various intervals to clean off the inside of the bulb. This is especially useful in some of the high-intensity short-life lamps, since by cleaning the inside of the bulb not only is the useful life increased many per cent, but the average amount of light given off during the life of the lamp, that is the lamp maintenance, is greatly increased.

Just recently (*8*) another method has been found to reduce blackening of the bulb due to the evaporation of the filament. This consists in putting screens in the bulb just above the filament in such a manner that the heated gas currents, after

passing the filament, must pass through these screens. With two screens, one connected to each lead, it was found that the screens caught so much of the vaporized tungsten, and thus kept it off the lamp bulb, that the useful life and the maintenance of its light output was increased many per cent. Since the lives of tungsten lamps are in general fixed for other considerations, such gains are used to increase the efficiency for the same life.

COILED COIL FILAMENTS

It is possible to reduce further the losses due to the gas surrounding the filament, particularly for lamps of small wattage, by coiling the coiled filament that is used in these lamps. This produces what has been called a coiled coil filament. For a lamp of the 60-watt size, an increase in efficiency of from 10 to 15 per cent is possible by this method. The percentage increase possible is less than this for the larger lamps and more for the smaller lamps. This results because the coiled coil further concentrates the filament and the protecting gas sheath covers the entire coiled coil and thus makes the per cent gas loss more nearly that of the larger lamp.

END LOSSES

Incandescent lamp filaments are cooled by the lead and support wires. As a result, the input of energy as well as the outputs of radiant energy and luminous flux are diminished. These reductions are summed up as end losses (*9*).

There are three methods of eliminating or correcting for end losses for purposes of study. The first employs very fine wire volt connections to points on the filament at a known distance apart, but far enough removed from the cooling leads or supports so that the part included will be at a uniform temperature. In the second method two filaments of the same diameter, but of different known lengths, are mounted on the same stem, the short one being long enough so that the temperature of its central part is not affected by end losses. The differences in voltage, light-output, etc., for the two filaments for the same current are the voltage drop, light-output, etc., for a uniformly heated filament,

the length of which is the difference in lengths of the two filaments. The third method depends upon measuring the variations in brightness of the filament from the uniformly heated part to the lead, and, from the temperature distribution thus obtained, computing the end-loss effects. All three methods have been used in determining the results reported in Tables 5 and 6, but, for the most part, the end-loss corrections shown were determined by the third method.

TABLE 5

Values of Q, $\sqrt{2\rho\eta}/Q$, and various effective voltage corrections for various maximum temperatures, T_m, for use with equations 1–8 in computing end losses

The junction temperature is assumed to be $T_m/4$

TEMPERATURE °K	Q CM.$^{-\frac{1}{2}}$	$\sqrt{2\rho\eta}/Q = \Delta V_B$ VOLTS	ΔV_C VOLTS	ΔV_D VOLTS	ΔV_E VOLTS
1000	.079	.066	.15	.20	.26
1200	.116	.089	.20	.27	.34
1400	.156	.112	.25	.34	.43
1600	.196	.137	.31	.41	.54
1800	.238	.162	.36	.49	.62
2000	.284	.189	.42	.57	.73
2200	.328	.217	.49	.65	.84
2400	.375	.246	.55	.74	.95
2600	.422	.276	.62	.83	1.06
2800	.470	.308	.69	.92	1.18
3000	.519	.340	.76	1.02	1.31
3200	.569	.374	.84	1.12	1.44

Figure 4 shows the variations occurring in temperature A, resistance B, radiation intensity C, and brightness D in a long, straight tungsten filament (r = 0.01 cm.) near a cooling lead in a vacuum lamp when the central maximum temperature is 2400°K. Distribution curves corresponding to any other maximum filament temperature and filament radius may be obtained from these curves by increasing all abscissae by the ratio of $[Q/\sqrt{r}]_0$ to $Q/\sqrt{r}$, where r is the radius and Q is a function of the maximum temperature and of certain properties of tungsten at this temperature. The fraction $Q/\sqrt{r}$ (see Table 5) refers to the conditions sought and $[Q/\sqrt{r}]_0$ to the condition diagrammed in Figure 4.

In Figure 4, the areas between the curves, the y-axis, and the line $y = 1.0$ represent end losses. In the case of curve B, suppose a line drawn at about $L = 0.27$ cm.; then the area below the curve and to the left of this line will be found equal to that part of the end-loss area above this curve and to the right of this line. Thus there is an effective filament shortening ΔL_B, in this case, which amounts to 0.27 cm. This means that the resistance

TABLE 6*

Extent of end-loss cooling for tungsten filaments of various sizes

TEMPERATURE, °K	RADIUS IN CENTIMETERS												
	.001	.002	.003	.005	.008	.010	.015	.020	.030	.050	.080	.100	.500
1000	3	4	5	6	8	9	11	12	15	20	25	28	65
1200	2	3	3.5	4.0	5.5	6.0	7.5	8.5	10	13	17	19	42
1400	1.5	2.0	2.5	3.0	4.0	4.5	5.5	6.5	8.0	10	13	14	32
1600	1.1	1.6	2.0	2.5	3.2	3.6	4.4	5.1	6.2	8.0	10	11	25
1800	.9	1.3	1.6	2.1	2.7	2.96	3.6	4.2	5.1	6.6	8.4	9.5	21
2000	.8	1.1	1.4	1.7	2.2	2.47	3.0	3.5	4.3	5.5	7.0	8.0	17
2200	.68	.96	1.2	1.5	1.9	2.15	2.6	3.0	3.7	4.8	6.1	6.8	15
2400	.59	.84	1.0	1.3	1.7	1.88	2.3	2.7	3.2	4.2	5.3	5.9	13
2600	.52	.74	.90	1.17	1.48	1.66	2.0	2.3	2.9	3.7	4.7	5.3	12
2800	.47	.67	.82	1.06	1.33	1.50	1.8	2.1	2.6	3.3	4.2	4.7	11
3000	.42	.60	.74	.95	1.21	1.35	1.7	1.9	2.3	3.0	3.8	4.3	10
3200	.39	.55	.67	.87	1.10	1.23	1.5	1.7	2.1	2.8	3.5	3.9	9

* Distance in centimeters from leads for various-sized long tungsten filaments, and various maximum temperatures, to points where the temperatures are only 0.1 per cent less than the maximum temperature ($7.0\sqrt{r}/Q$). For temperatures 0.01 per cent less the distances are 4/3 those given; for temperatures 1 per cent lower than the maximum the distances are 2/3 those given. For short filaments the filament half-lengths are about 13 per cent greater.

of the filament for the condition specified with the cooling leads is equal to the resistance of a uniformly heated filament which is 0.27 cm. shorter for each junction of filament to lead wires. For curves C and D, the effective filament shortenings, ΔL_C and ΔL_D, are about 0.60 and 0.80 cm. Effective filament shortenings vary with filament radius, maximum filament temperature, and the property (e.g., energy input, etc.) studied.

EFFECTIVE FILAMENT SHORTENING DUE TO END LOSSES

The difference between the supply rate and the radiation rate near a cooled support or lead is the rate of conduction of heat to it. This heat-conduction loss is represented in Figure 4 by the area between curves B and C. If the ordinates are expressed in watts per cm. of filament length, the heat-conduction loss is

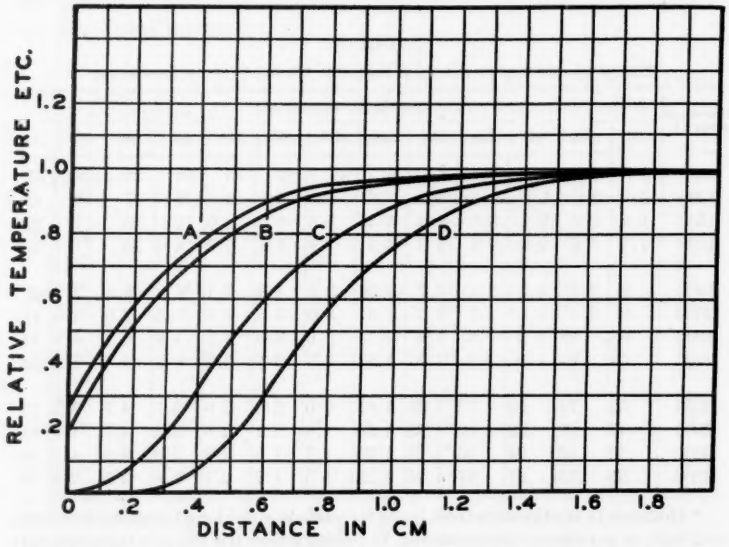

FIG. 4. Various distribution curves near a cooling junction for a long tungsten wire (r = 0.01 cm) electrically heated in vacuo to a central maximum temperature of 2400°K. (A) temperature; (B) resistance; (C) radiation intensity; (D) brightness.

given directly in watts. For the case represented, it is the wattage of a portion of the uniformly heated filament whose length is 0.33 cm., the difference between the effective shortenings, 0.60 cm. and 0.27 cm. In general, this loss is given relatively by $\frac{\Delta L_C - \Delta L_B}{L}$, where L is the filament half-length. Equations that follow may be used for its evaluation.

The effective filament shortenings from the various standpoints are given by

$$\Delta L_A = 0.88\sqrt{r}/Q \text{ (heat content)} \quad (1)$$
$$\Delta L_B = 1.00\sqrt{r}/Q \text{ (energy input, voltage, or resistance)} \quad (2)$$
$$\Delta L_C = 2.25\sqrt{r}/Q \text{ (radiation output)} \quad (3)$$
$$\Delta L_D = 3.00\sqrt{r}/Q \text{ (light emission} \quad (4)$$

These equations show that all shortenings vary directly as $\sqrt{r}$ and inversely as Q (Table 5), a function of the maximum temperature. These equations give end-loss corrections directly when the filament's length, radius, and maximum temperature are known.

EFFECTIVE VOLTAGE CHANGE DUE TO END LOSSES

When the filament length and radius have not been measured directly, the end-loss corrections may be obtained from a consideration of the effective voltage corrections (*10*), ΔV_A, etc., corresponding to the various standpoints. Limiting consideration to the case of a filament with only two leads, and representing by L, V, etc., the filament half-length, half the observed voltage, etc., these effective voltage corrections become the difference between the voltage drop over L, were it uniformly heated throughout, and the voltage drop over a shortened length of uniformly heated filament yielding the observed radiation, or luminous or thermionic output. These shortened lengths are $(L - \Delta L_A)$, etc. The voltage corrections sought are the products of ΔL_A, ΔL_B, etc., by dV/dL for a uniformly heated filament. Since dV/dL equals $\sqrt{2\rho\eta/r}$, where ρ is the resistivity and η the total radiation intensity, from equations 1 to 4 there follow:

$$\Delta V_A = 0.88\sqrt{2\rho\eta}/Q \text{ (heat content)} \quad (5)$$
$$\Delta V_B = 1.00\sqrt{2\rho\eta}/Q \text{ (energy, input, voltage, or resistance)} \quad (6)$$
$$\Delta V_C = 2.25\sqrt{2\rho\eta}/Q \text{ (radiation output)} \quad (7)$$
$$\Delta V_D = 3.00\sqrt{2\rho\eta}/Q \text{ ((light emission)} \quad (8)$$

These corrections (Table 5) depend upon the maximum temperature T, but not upon dimensions of the filament.

Empirically the variation of ΔV_B with T_m is closely given by

$$\Delta V_B = \tfrac{1}{2}\,(0.00028T_m - 0.17 \tag{9}$$

Other ΔV's can be represented by similar empirical equations. To illustrate the use of these equations and the table, suppose the light emission correction is desired for a filament with two leads between which there is a 10 volt drop and a central temperature of 2800°K. The factor "f" by which the observed emission must be multiplied to obtain the emission, were the filament uniformly heated throughout its length, is given by

$$\text{"}f\text{"} = \frac{L}{L - \Delta L_D} = \frac{\dfrac{LdV}{dL}}{(L - \Delta L_D)\dfrac{dV}{dL}} = \frac{V + \Delta V_B}{V + \Delta V_B - \Delta V_D} \tag{10}$$

Since for this case $V = 5$ volts, $\Delta V_B = 0.31$ volts, and $\Delta V_D = 0.92$ volts, the correction factor is 1.21.

From the value of "f" given by the first part of equation 10, *i.e.*, $\dfrac{L}{L - \Delta L_D}$, it can be shown that the percentage end-loss corrections for different temperatures for filaments of the same size in similar lamps vary inversely as the values of Q given in Table 5. For different sized filaments in similar lamps the percentage correction varies as $\sqrt{r}$. Thus, if the end-loss correction is known for one maximum temperature for a particular filament, such correction can be easily computed for other maximum temperatures and for filaments of different radii for lamps similarly constructed.

Distances along a filament from a cooling lead to points where the temperatures are within 0.1 per cent of those of the uniformly heated portions are given in Table 6. If temperatures within 0.01 per cent are desired, take distances four-thirds times those given in the table. If temperatures within 1 per cent only are desired, take lengths two-thirds times those here listed. Since the temperature at the center of short filaments is lowered by the cooling of both leads, their half-lengths must be about 13 per cent greater than lengths given in the table, in order that their central temperatures shall not be more than these same percentages lower

than the central temperatures of long filaments when heated by the same currents. Thus, for a filament with a 0.01 cm. radius and a central temperature of 1800°K, a total filament length of twice 3.3 cm. or 6.6 cm. must be used in order that its central temperature shall not be more than 1.8° lower than that of a long filament of the same cross-section heated with the same current. Distances for other properties may be obtained from their temperature relations.

Some indications of the energy input and light output end losses for commercial lamps are of interest (*11*). The older type 40-watt 115-volt vacuum tungsten lamp with a straight filament 51 cm. long and 0.038 mm. in diameter has two large copper leads and eleven small molybdenum hook supports. The temperature is about 2450°K. While the lead-junction temperature is only a little greater than $T_m/4$, the support temperatures are considerably greater, about 1750°K. Because of this high value, equations 1–9 cannot be applied directly. By graphical means employing the curves of Figure 4, their contribution to the total end losses may be computed. In this way, total effective shortenings from the energy input and light output standpoints of 1.1 and 5.2 cm. have been found. These correspond to 2.2 and 10 per cent, whence there is a decrease in efficiency of 7.8 per cent.

By using other materials for the leads and supports, or smaller wires for supports, and by eliminating as many of the supports as possible, such end losses have been reduced until now they amount to about 2 per cent for the 115-volt lamp of ordinary size. The removal of a single support from an ordinary tungsten lamp results in an increase in efficiency of about 0.5 per cent. Improvement along these lines has been largely due to an improved quality of the filament wire with respect to its non-sagging properties. The lamp engineers have developed a wire that will retain its shape at high temperatures much more satisfactorily than the older wire. Some data on the end losses of present day lamps are included in Table 19.

NON-SAG WIRE

It was at first quite difficult to coil the wire that was then being used for lamp filaments and have these coils retain their shape

when they were operated at high temperatures. Experiments showed how to improve the qualities of the wire so that not only could it be made into a coil, but the diameter of the coils could be increased and the resulting coiled filaments retain their shape when operated at a high temperature without as many supports as formerly. The old 40-watt vacuum tungsten lamp had eleven supports while the new gas-filled lamp of the same size (with a coiled filament) has only three supports. This change alone accounts for about 4 per cent gain in efficiency.

LAMP LIFE AND FILAMENT DIAMETER

The life of a lamp with a tungsten filament at a given temperature increases with an increase in the filament diameter, since the cross section of the filament—which determines the resistance and thus the variation of the temperature—depends upon the square of the diameter while the amount of material vaporized depends upon the surface used, which, in turn, varies directly as the diameter. Since in general 115-volt lamps of all sizes are operated for approximately one thousand hours life, this means that the larger filament lamps can be operated at a somewhat higher temperature for the same life, which again means that the larger filament lamps operate at a higher efficiency than the smaller lamps.

For convenience, tungsten lamps may be divided into three classes, depending upon the size and voltage, and upon the service for which they are intended. These classes are: lamps for general lighting purposes, lamps for special lighting purposes, and miniature lamps. In order to satisfy all the various lighting needs, tungsten lamps are now made in a great variety of sizes and shapes. The smallest lamp made is the grain-of-wheat lamp that is used by the surgeon as a source of light for internal investigation. The largest lamp regularly made is the 10-kw. 115-volt lamp; but several 50-kw. 115-volt lamps have been made for demonstration purposes.

LAMPS FOR GENERAL LIGHTING

For the 115-volt lamps that are used for general lighting purposes, the efficiency (lumens per watt) for a definite life in hours

is very important, since these two characteristics largely determine the cost of the light obtained. Economic considerations determine the life of these lamps because light is produced at the least cost when the cost of the lamp is a definite percentage of the cost of the power used to operate it during its life. Some of the characteristics of a number of lamps that are used for general lighting purposes are given in Table 7.

TABLE 7

Characteristics of some lamps used for general lighting purposes

LAMP	LUMENS/WATT	LUMENS	FILAMENT TEMPERATURE
6-watt vacuum	6.9	40	2400°K
15-watt vacuum	9.4	140	2520
25-watt vacuum	10.3	258	2550
40-watt gas-filled	11.1	444	2710
60-watt gas-filled	12.9	775	2770
75-watt gas-filled	14.3	1075	2830
100-watt gas-filled	15.5	1550	2845
150-watt gas-filled	16.9	2535	2865
200-watt gas-filled	17.5	3500	2880
300-watt gas-filled	19.0	5700	2915
500-watt gas-filled	20.0	10000	2950
1000-watt gas-filled	20.7	20700	2970
1500-watt gas-filled	21.7	32450	3015

LAMPS FOR SPECIAL SERVICES

For many services for which special lamps are constructed, the overall efficiency in lumens per watt is of secondary importance. This is because many of these lamps are used for purposes where the problem is to get as great an amount of light as possible, for the wattage used, through a small opening or upon a certain area. This, in turn, requires that the filaments be concentrated into a very small space. Thus sometimes the service is more important than the life or the efficiency, and the requirement for a great amount of light from a small area is so important that at times this results in certain special lamps being operated at a very short life.

There are many services that require special lamps; and

TABLE 8

Characteristics of lamps intended for special services

LAMPS	VOLTS	CURRENT	WATTS	LUMENS	LUMENS/WATT		TEMPERATURE (DEG. K)
Street Series		6.6		1000	15.7		2860
		6.6		2500	17.2		2885
		6.6		4000	18.3		2915
		6.6		6000	18.5		2920
		15.0		4000	19.0		2950
		20.0		6000	20.1		2995
		20.0		10000	20.0		3000
		20.0		15000	20.1		3000
		20.0		25000	20.6		3010
CX Lamps	115		60		13.6		2840
	115		250		19.0		2970
	115		500		21.3		3025
Airport Lighting	32		1500		28.0		3250
	32		3000		29.5		3250
Studio or Airport Floodlighting	115		5000		29.0		3300
	115		10000		29.5		3320
Floodlight	115		500		17.3		2940
	115		1000		19.3		3015
	115		1500		20.2		3050
Spotlight	115		250		17.7		2930
	115		400		19.6		3050
	115		1000		23.0		3145
	115		2000		24.5		3140
Projection (monoplane)	115	82*	300	7010	24.0	820†	3230
	115	156*	500	13280	26.3	1545†	3265
	30	148*	900	24570	26.5	2860†	3290
Projection (biplane)	115	68*	500	12420	26.0	1700†	3295
	115	89*	750	19360	26.0	2670†	3355
	115	132*	1000	29160	27.6	4045†	3360
Projection (coiled coil)							
4 segments	115	16*	50	820	16.2	80†	2930
4 "	115	27*	100	1980	18.7	200†	2980
2 "	115	41*	200	5000	23.0	460†	3100
3 "	115	31*	100	1900	18.7	185†	2950
2 "	115	46*	200	4370	20.5	425†	3000
3 "	115	55*	200	3930	21.3	390†	2990
2 "	115	66*	300	7220	24.0	720†	3100
Photoflood	115		250	8600			3490
	115		1000	32000			3410
Movieflood	115		2000	67000			3430

* Area light source in square millimeters.

† Candlepower in a direction perpendicular to plane of filament.

whenever there is sufficient demand, an attempt is made to develop a lamp for the special service. The characteristics of a number of the lamps developed for special services have been measured. The results are given in Table 8. The lamps selected were intended to be representative of the lines of lamps designed for various services.

STREET LIGHTING

The lighting of streets is a good example of a special service that was found important enough to justify the development of lamps for that particular problem. This resulted in a line of series lamps for several reasons; one important reason was the then existing series distribution systems laid out in various cities for the purpose of operating the old arc lamps. The availability of these high-voltage circuits makes it possible to use, in series, lamps of low voltages and relatively high currents, which is fortunate; a lamp of small wattage with high current can be made to have a higher efficiency than is possible using a lamp of high voltage and low current. This is because a high-current lamp has a filament of larger diameter than the lamp of small current, and the efficiency of a gas-filled tungsten lamp increases rapidly with an increase in the filament diameter up to a filament of about the diameter of that of the ordinary 500-watt 115-volt lamp. Constant-current operation, however, results in a slight sacrifice of initial efficiency, since constant-current lamps do not live as long as constant-voltage lamps of the same size and initial rating. These lamps are made in a number of sizes to satisfy the demand for different amounts of light on different streets. Since street lighting is generally sold on the basis of a definite illumination, these lamps are rated in lumens.

CX LAMPS

A line of lamps called CX lamps has been developed for the production of intense infrared radiation combined with mild ultraviolet. The life of these lamps has been shortened to take advantage of the increased radiation due to the higher temperature for the shorter life. These lamps are manufactured with a

special glass bulb which has a high transmission in the ultraviolet down to wave lengths about 2900A and transmits some energy down to wave lengths of about 2600 to 2700A. Thus, the mild ultraviolet radiated by the tungsten filament at the higher temperature at which it is operated in this lamp is transmitted.

FLOODLIGHTING LAMPS

Another service for which special lamps have been developed is the floodlighting of studios and airports. Both these services require very high intensities, and since high wattage can be used, 5,000- and 10,000-watt lamps have been developed for this illumination. Some lamps of lower wattage are also used for airport floodlighting. Lamps have also been developed for the floodlighting of buildings and certain important displays. These floodlight lamps are generally used in reflectors which require the filament to be specially placed to produce the best results.

SPOTLIGHTING LAMPS

Another line of lamps somewhat similar to the floodlight lamps, and intended for a similar service, are the spotlight lamps. These lamps are also used with reflectors or lenses so the filaments must be arranged in such a position as to give the best source for this purpose. Spotlighting lamps are used for throwing a spot of light of high intensity on some displays and stage settings. These lamps are designed for a short life since the wattage is somewhat limited and high intensity is necessary.

PROJECTION LAMPS

The projection of moving pictures, either with the small home movie projection machine or with the larger machines used to project regular pictures, requires a special lamp. This service is quite varied and thus requires lamps varying in size from about a 50-watt lamp, for the small moving picture machine, to lamps of 1,000-watt rating or larger for the larger projection machines. For this service, the problem is to get as much light as possible, for the wattage used, through the projection machine onto the

screen; and for this reason the filaments are concentrated and the lamps designed for a life of 25 to 100 hours, since the amount of light from a given filament increases very rapidly as the life is shortened. The question here is how much light is radiated in a definite direction within a definite cone—and that, too, from a light source of definite small size. Many of these lamps have their filaments arranged in two planes, with the coils in one plane immediately behind the space between the coils of the plane in front, thus giving a source of small area almost filled with the light source. This very greatly increases the amount of light that can be sent through the projection instrument. These biplane projection lamps have a somewhat lower lumen-per-watt rating than the monoplane lamps, but they have a much more uniform light source. The light source area and the candlepower in a direction perpendicular to the plane of the filament are given in Table 8. In addition, a line of 115-volt coiled coil lamps has been developed for this purpose. These consist of lamps ranging in size from 50-watts to 300-watts, with 2 or 3 thin segments in a plane. Data on these lamps are given in Table 8.

When taking and projecting sound motion pictures, the very special illumination for both making the sound record and for reproduction requires a high-intensity lamp with a filament of very special dimensions. A line of photocell exciter and recorder lamps has been developed for this service.

PHOTOFLOOD LAMPS

Another line of lamps for special purposes includes the photoflood and movieflood lamps (*12*) intended for taking regular, home movie, and color pictures. For these purposes a great amount of light is necessary, and it should be of as high color-temperature as possible, since light of a high color-temperature is more effective photographically than light of low color-temperature. As it is so important to have a great amount of light at not too high wattage, and also to obtain a high color-temperature of the source, these lamps are operated at the very short life of from 2 to 15 hours, depending upon the size of the lamp. A comparison of the temperature and lumen output of

the 250-watt photoflood and the ordinary 500-watt lamp will show what has been gained both in color-temperature and amount of light output by designing the photoflood for the very short life. This increase in color-temperature is very important, since the photographic effect of a source for the same amount of wattage is increased by a factor of about 30 to 40 per cent for a 100° increase in temperature at 3000°K. Thus the increase in temperature of the 250-watt photoflood lamp results in an increase in photographic effectiveness of the lamp by a factor of three or four. Data on the photographic effectiveness of some of these photographic lamps are given in Table 9.

TABLE 9

Characteristics of photographic lamps

LAMP	DIAMETER OF BULB (CM.)	TIME FROM TURNING ON CURRENT TO START OF FLASH (SECONDS)	DURATION OF FLASH (SECONDS)	TOTAL LIGHT OUTPUT (LUMEN SECONDS)	MAXIMUM INTENSITY (MILLION LUMENS)	RELATIVE PHOTOGRAPHIC EFFECTIVENESS
#10	6.0	0.010	0.050	16,000	1.4	0.4
#20	7.3	0.009	0.060	40,000	3.1	1.0
#75	10.2	0.017	0.100	169,000	10.2	4.2
		WATTS	COLOR TEMPERATURE			
#1 photoflood		250	3490°K	8,600		0.023*
#4 photoflood		1,000	3410	32,000		0.08*
Movieflood		2,000	3430	67,000		0.15*
5 K.W. lamp		5,000	3420	145,000		3.4*

* Time 0.1 second.

MINIATURE LAMPS

In general, a miniature lamp is one that is small in size and is intended for use on a voltage much less than that ordinarily used for large lamps. Most of these small lamps are operated from batteries because they are used in services where both the lamp and source of power must be portable. There are two general classes of miniature lamps, *i.e.*, automobile lamps and flashlight lamps, with several other types for special purposes such as the lighting of Christmas trees, sewing machines, and

radio panels, and the lamps used by miners and those employed in sound pictures. There are a number of the automobile and the flashlight types of lamps manufactured, but standardization has resulted in three types of flashlight lamps and nine types of automobile lamps constituting over 90 per cent of the total flashlight and automobile demand.

The relation between the temperature of the filament and the

TABLE 10

Characteristics of automobile lamps

MAZDA LAMP NO.	SERVICE	VOLTAGE	CANDLE-POWER	WATTS PER SPHERICAL CANDLE	MAXIMUM TEMPERATURE, °K
51	Indicator lamp	7.5	0.9	1.7	2450
55	Indicator lamp	6.5	1.9	1.4	2715
63	Rear, instrument board, step, and auxiliary headlight	6.85	2.9	1.32	2820
67	Rear, instrument board, step, and auxiliary headlight	13.5	2.9	1.27	2810
81	Dome, panel	6.9	6.3	1.01	2915
87	Signal	6.75	14.4	0.80	2980
1141	Headlight	13	21.9	0.70	2960
1142	Motor coach	12.5	20.6	0.80	2885
1158	Headlight. Ford cars wired for two-filament lamps	6.5	21	0.75	2980
			3	1.2	2830
1183	Spotlight	5.5	49.1	0.72	3055
1000	Headlight depressible beam	6	31	0.73	2965
2320	Prefocus headlight:				
	Major filament	6.2	32	0.80	2940
	Minor filament	6.5	21	0.86	2945
2330	Prefocus headlight:				
	Major filament	6.2	32	0.81	2970
	Minor filament	6.2	32	0.81	2970

efficiency of the miniature lamp is quite different from that of a large lamp. This is because the filament in small lamps is so short that the loss due to conduction of heat by the leads lowers the temperature of the filament for a greater portion of its entire length. In some of the smaller lamps the effect of this heat conduction of the leads in reducing the temperature of the filament extends so far along the filament that there is but a small part of the filament at maximum temperature. In the

large lamps the loss of efficiency chargeable to the end losses amounts to about 3 to 5 per cent, while in the small lamps it may amount to as much as 30 per cent. The data (*13*) given in

TABLE 11

Characteristics of flashlight lamps

LAMP NO.	VOLTAGE	CANDLEPOWER	WATTS PER SPHERICAL CANDLE	MAXIMUM TEMPERATURE, °K
1	2.25	0.40	1.39	2665
13	3.70	0.98	1.11	2670
14	2.47	0.54	1.41	2700
19	1.25	0.19	4.10	2570
31	6.15	2.14	0.87	2770
35	2.40	1.45	1.35	2635
112	1.20	0.06	3.9	2610
222	2.25	0.40	1.40	2845

TABLE 12

Characteristics of special miniature lamps

LAMP	VOLTAGE	CANDLEPOWER	WATTS PER SPHERICAL CANDLE	MAXIMUM TEMPERATURE, °K
Hand lantern	5.00	0.64	1.19	2610
Miners' lamp: Major	2.4	1.31	2.11	2725
Minor	2.5	0.83	2.29	2700
Radio Panel: No. 40	6	0.60	1.52	2485
No. 41	2.5	0.51	2.19	2400
Grain-o'-wheat surgical lamp	1.5	0.028	6.0	2115
Christmas tree	15	4.7	1.0	2625
Toy train	18	3.7	1.45	2695
Photocell exciter lamp	10	80	0.62	3020
	10	138	0.53	3120
	8.5	56	0.62	3040
	8	12	1.27	2650
		LUMENS	LUMENS PER WATT	
Sewing machine	115	122	7.5	2345
Sign, clear	115	85	8.4	2400
Indicator (5-watt lamp)	115	32.5	6.5	2300

Tables 10, 11, and 12 were obtained by measuring about ten lamps of each type that had been selected from stock, each type being measured at the test voltage given in the tables. The

light output of most of the lamps was measured by the Testing Section of the Standardizing Department at Nela Park.

The life of a miniature lamp is usually made much shorter than that of a large lamp because it is so often necessary to obtain as much light as possible; and since the light output increases very fast as the designed life of a lamp is shortened, the life is sacrificed to gain the added light output. The life of the flashlight types of lamp varies from about 3 to about 75 hrs. and that of the automobile types of lamp ranges from 100 to about 300 hrs. The lamps used in sound-picture work have a life of 25 to 50 hrs.

AUTOMOBILE LAMPS

Most automobile lamps used by pleasure cars are operated from a 6- to 8-volt battery, while many of the trucks and buses require lamps designed for 12 to 15 volts for use on the higher voltage battery employed in their electrical service.

The automobile headlight lamp is manufactured under probably more exacting specifications than any other lamp. This is particularly true with respect to the location of the filament with regard to the base of the lamp. The position of the filament with respect to the axis of the base and the distance between the base and the filament is kept so nearly uniform that it is possible to have the headlights of an automobile well focussed for one lamp and then remove the lamp, put in another and still find the headlights in good focus. This accuracy is obtained by the use of a special apparatus for mounting the filaments on the leads, sealing the mount in the bulb, and placing the base on the lamp.

The two types of automobile headlight lamps have double filaments. In one the extra filament is used for depressing the beam and for producing less intense light. To satisfy a need for more light, the high-power headlight lamp and spotlight lamp were brought out about a year ago. These lamps (No. 1000 and No. 1183), as can be seen from Table 10, give 50 to 100 per cent more light than the regular headlight and spotlight lamp. In Table 10 the temperature, candlepower, and some of the electrical characteristics are also given for a number of the automobile lamps.

FLASHLIGHT LAMPS

Flashlight lamps are used in a number of different types of units and, in general, are operated from dry batteries. Some of the smaller lamps are operated from only one small dry cell, while others are operated from three or more large dry cells. In Table 11 are given the temperature and some of the other characteristics of a number of such lamps.

GRAIN-O'-WHEAT LAMP

The smallest lamp made is the "Grain-o'-wheat" surgical lamp that is used by physicians as a light source for internal examination. The bulb of this little lamp is a tube about 2 mm. in diameter and about 8.7 mm. long. The complete lamp weighs 0.06 gram. It operates from a single dry cell, consumes 0.17 watt, and as shown in Table 12 gives only 0.028 mean spherical candlepower.

In Table 12 are also listed a number of other special miniature lamps together with their filament temperatures and some of their other characteristics. When determining the temperature of the Christmas tree lamps, it was necessary to use lamps having smooth bulbs because the irregular surface of the bulbs ordinarily used made it impossible to obtain an image of the filament in the optical pyrometer.

VERY LARGE LAMPS

A few years ago a 2000- or a 2500-watt incandescent lamp seemed large; but now, as the result of developmental work, 10,000-watt lamps are manufactured and are regularly used in the motion-picture industry, airport lighting, and in some other places where high intensity illumination is desired. To date, the largest incandescent unit that has been attempted is the 120-volt 50,000-watt lamp, of which only a few have been made, for special illumination and display. These have operated successfully and the strength of the various parts has allowed the lamps to be shipped from coast to coast without any breakage; thus, it has been demonstrated that a successful 50-kw. lamp can be made if necessary.

Sometimes comparisons and figures are given concerning these large lamps without any real conceptions as to what the figures really mean. To make a lamp that will consume 50 kw. requires some very special construction, for this is really a large amount of power—it would take almost the entire output of a 70-h.p. engine to furnish enough electricity to operate one of these lamps.

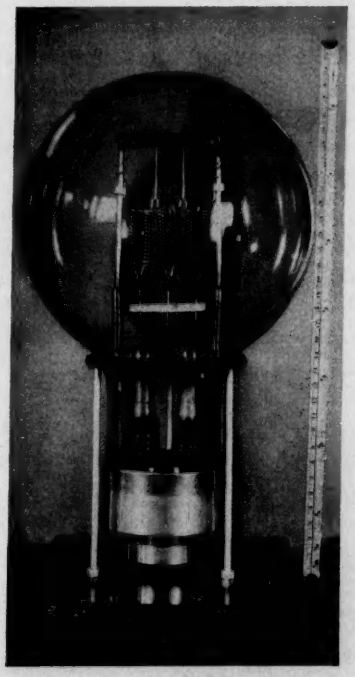

FIG. 5. Complete 50-kw. lamp. At the right of the lamp is a 36 inch scale to show the size of the lamp.

This amount of power would operate 500 to 1000 lamps such as are regularly used in our reading lamps. Also this amount of power would be sufficient to operate enough incandescent lamps to light satisfactorily a mile of city thoroughfare.

A picture of the 50-kw. lamp is shown in Figure 5. The filament, like that of all gas-filled lamps, is coiled, and in this lamp

it consists of six segments mounted in a plane. The filaments for the ordinary 40- to 100-watt gas-filled lamps are coiled by machinery at a rate of three to five thousand revolutions per minute. It is much more difficult to wind a coil of tungsten wire of the size necessary (150 mils in diameter) for the 50,000-watt lamp. For this purpose, a large machine lathe was used and an iron rod about three-eighths inch in diameter was used as the mandrel. The tungsten wire was heated to a dull red with a blast torch, and the winding was done on the lathe by hand at a speed of about fifteen revolutions per minute.

At first a great deal of trouble was experienced due to the cracking of the seals when they were made similar to the ones used for the smaller lamps, *i.e.*, two pieces of tungsten sealed in the glass press. To overcome this trouble it was found necessary to use copper-to-glass seals for these large lamps. This solved two very troublesome problems: the one already spoken of, *i.e.*, the cracking of the seals; the other, the method of carrying the filament and its supports. The filament and its supports are so heavy (about 6.5 lb.) it was found practically impossible to support them in the usual manner by means of the leads sealed through the glass press. With the copper-to-glass seal the filament and its supports are carried on heavy copper rods passing through the copper tubing that is joined to the glass, as shown in Figure 5. The bulb and the filament with its leads are both supported by the large base shown in the picture. The complete 50-kw. lamp weighs over thirty-five pounds.

It was not found practical to make the bulbs of the 10- or 50-kw. lamps as large in proportion to their wattages as the smaller lamps. Thus the radiation through the bulb is several times greater for these large lamps than for the smaller ones, and this caused the bulb to operate at a high temperature. For this reason it was found necessary to use pyrex for the bulbs. These large lamps are designed for a service where the primary consideration is a great amount of light. For this reason they are designed for 100 hrs. of life, since a tungsten filament has a higher efficiency at the high temperature corresponding to this life, and thus much more light can be obtained from the same size filament.

If the glass blackens from the vaporization of the tungsten, it will become much hotter, since the blackened glass absorbs a larger percentage of the energy that falls upon it than the clear glass does. If this is allowed to continue, the glass becomes so hot that it may soften and blow out at this point, causing the lamp to fail. The use of tungsten powder for cleaning this tungsten deposit off the inside of the bulb is an important factor in these large lamps.

The weight of the filament for the 10-kw. lamp is about 39 grams, and for the 50-kw. lamp about 740 grams. The amount of tungsten used for the filament in a single 50-kw. lamp is sufficient to make about 120,000 filaments for the 40-watt 115-volt lamps. The bulb for the 10-kw. lamp is spherical in shape and

TABLE 13
Characteristics of large lamps

LAMP	VOLTS	TEMPERATURE	LUMENS	MAXIMUM CANDLEPOWER	LUMENS/WATT
10-kw.	120	3300°K	280,000	33,000	29
50-kw.	120	3300°K	1,400,000	166,000	29

about 12 in. in diameter, while the one for the 50-kw. lamp, also spherical, is about 20 in. in diameter.

In Table 13 are given some of the characteristics of the 10- and 50-kw. lamps (*14*).

It is interesting to compare some of the characteristics of the largest and the smallest lamps now manufactured. The smallest lamp made is the "Grain-of-wheat" used for surgical purposes. A picture of one of these little lamps is shown on the small vertical rod just at the right of the center at the bottom of the picture of the large lamp in Figure 5. It is so small that it appears as a point. This lamp has as a bulb a tube about 2 mm. in diameter and about 8.7 mm. long. The complete lamp weighs 0.06 gram. The horizontal candlepower of this little lamp is 0.028 as compared to 166,000 candles for a 50-kw. lamp. The temperature of operation of the grain-of-wheat lamp is 2100°K, while the large lamp operates at a temperature of about 3300°K. The small lamp operates from a single dry cell and consumes 0.17 watt.

Thus it is seen that the wattage of the large lamp is about 300,000 times that of the smaller, and the amount of light radiated by the 50-kw. lamp is about 5,000,000 times that of the little lamp. The tungsten used for the filament of the 50-kw. lamp would make filaments for about 21,000,000 of the little lamps.

BI-POST LAMP CONSTRUCTION

There has been developed recently at Nela Park (*15*) a new construction for higher wattage lamps which has a number of

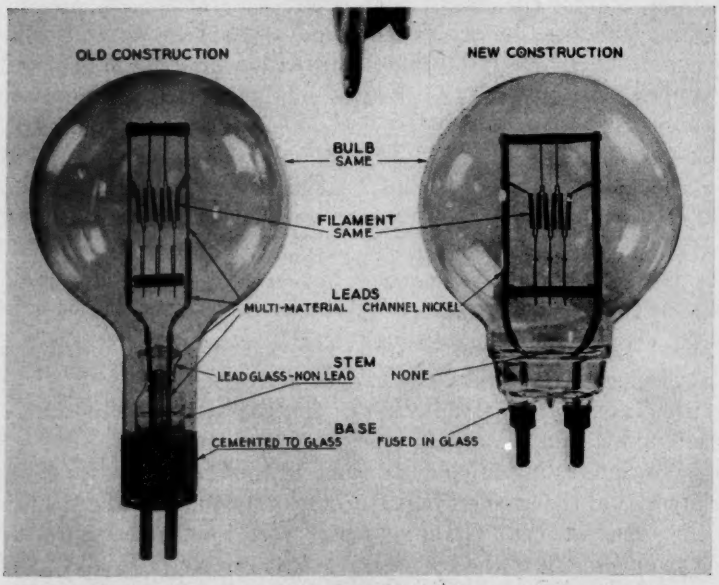

FIG. 6. Comparative construction of the bi-post lamp with the older form

decided advantages over the commonly accepted design followed since Edison made his first lamp in 1879. It is very difficult to seal through glass a lead large enough to carry current for very large lamps. This difficulty was overcome by copper to glass seal in the 50 kw. construction as shown in Figure 5. At first, following precedent, the copper part of the seal was placed inside the bulb, as shown, and the outside contacts provided later. It

was but a small step (after it had been taken (*15*)) to reverse this and make these copper parts the outside connections, and lo, the bipost construction was born! Some of the advantages of the bipost construction over the older form are illustrated in

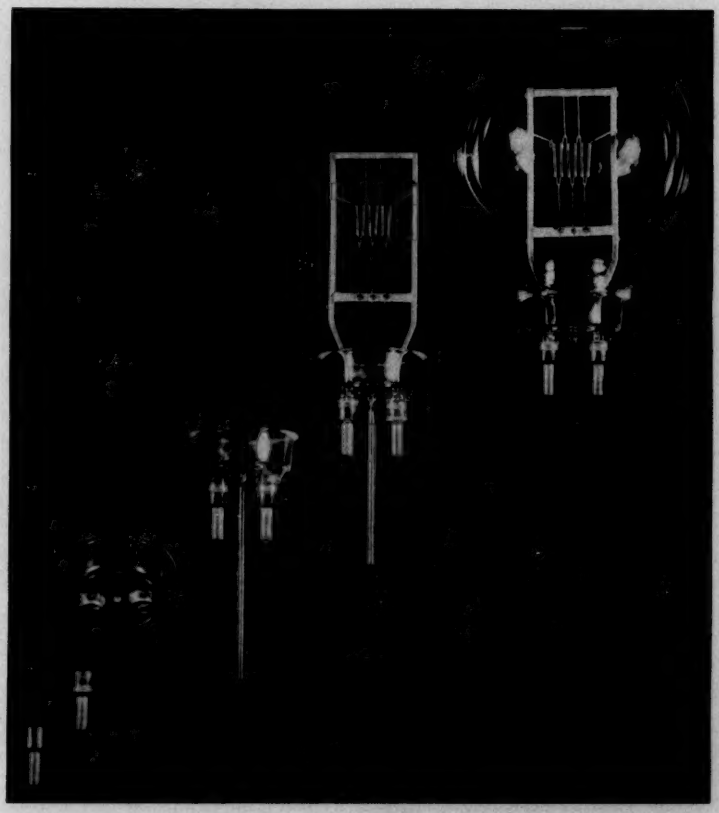

FIG. 7. Parts of the bi-post lamp

Figure 6, which shows a picture of the old and new lamps. Besides the saving in material and labor in constructing lamps, the outstanding advantage of the new construction is the ease with which the position of the filament can be accurately located

with respect to the prong base and the rigidity of the supports—all accomplished without making the mount unduly heavy.

A word should be said about the glass for this new construction. Figure 7 shows the glass parts for the lamp. The bulb is cut

FIG. 8. A new 1000-watt bi-post Mazda lamp

to fit the glass cup that holds the two copper seals through which the supports for the filament are brought into the lamp bulb. The bulb is welded to this glass cup by means of a small pointed flame. This is a true weld and not a blown joint, since there is

no blowing while it is being made. The result is a very rigid and satisfactory seal.

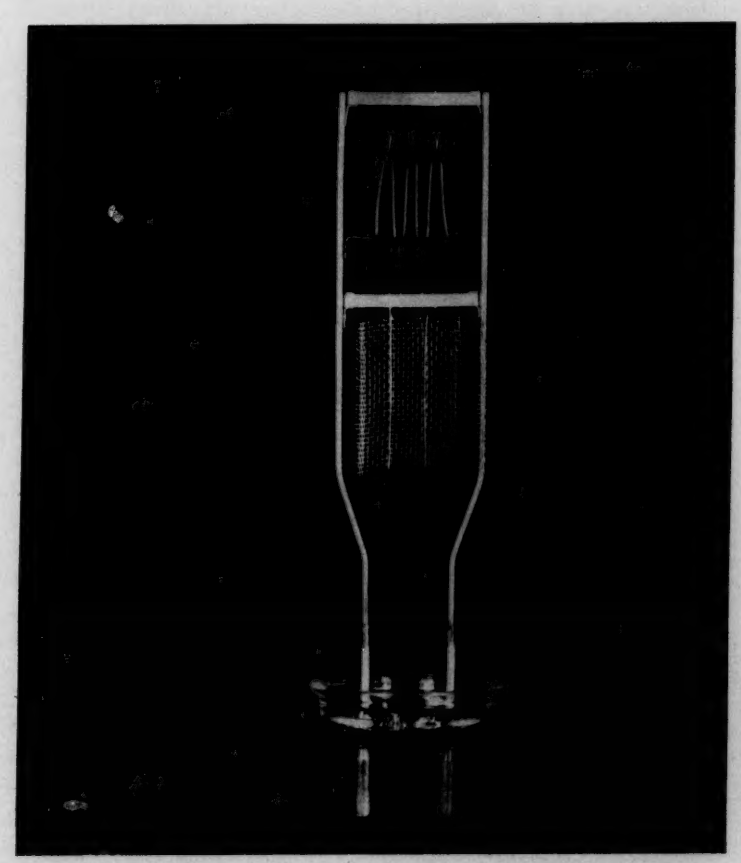

FIG. 9. Filament mount for the new 1000-watt bi-post Mazda lamp showing the screen for collecting the vaporized tungsten.

Many of these larger lamps are in bulbs much smaller than the wattage data from smaller lamps would dictate. The bulbs are apt to become very hot, a condition which forces the use of

some hard glass, such as pyrex. The use of hard glass has made the present-day construction of this lamp possible.

In attempting to carry the copper-glass seal down to small sizes, difficulties were encountered, so a new metal-to-glass seal was used (*16*). A glass can be made that will match the expansion of the new metal (Fernico), but for lamp making reasons the engineers wanted to use pyrex, which has about 20 per cent less expansion than the Fernico. A special technique was developed by the engineers that enables them to seal this metal to the pyrex as shown in Figure 7. A very small bipost lamp was thus possible, with the prongs and seals of the order 5–8 mm. in diameter. By the use of this new seal there was recently developed a 1000-watt Mazda lamp for general lighting service. The bulb for this lamp is 3 ins. in diameter and 9.125 ins. long. This lamp, shown in Figure 8, offers many advantages and possibilities to the fixture designer. The filament mount is shown in Figure 9, where also is shown the screen above the filament that gathers the evaporated tungsten which would otherwise be deposited on the walls of the glass bulb and, by blackening them, interfere with the transmission of the light. This new construction seems to offer possibilities for application to lamps of many other sizes.

LUMILINE LAMP

Another illustration of the principle that producing light in the right place may be preferred to a high overall efficiency in lumens per watt, is the "lumiline" lamp. For show-window, counter, and architectural lighting a source of light of small transverse dimensions and uniform along its length is much in demand. Tubular bulbs, $\frac{3}{4}$ in. by 18 in., with axial filaments nearly as long as the bulbs, with "sockets" which permit bringing them practically end to end, furnish such a line source. So extended a source cannot to advantage be used in a gas atmosphere, hence the efficiency is lower than that of the standard lamp of the same wattage. A thick coating on the bulb, designed to secure greater uniformity in brightness, may further reduce the efficiency, while improving the lamp for the service for which it is intended.

PRE-FOCUSED LAMPS

Precision in the location of the filament of a lamp for general illumination is not particularly important, since displacements are effectively merely changes in the comparatively large distances to the surfaces illuminated. When, however, a lamp is to be used for projection purposes, small displacements relative to nearby optical parts—mirrors or lenses—are magnified into gigantic changes in the reflected or refracted beam. The accuracy thus demanded may be secured either by "prefocusing" the lamp with respect to a metal ring which can then be seated precisely—and interchangeably—in the projection apparatus, which may be a flashlight lens and/or reflector, a projection machine for slides or motion-picture film.

SPECTRAL DISTRIBUTION AND FILAMENT TEMPERATURE

The spectral distribution of the energy radiated by a tungsten filament lamp is determined to a large extent by the temperature of the filament. The normal temperature of operation of the filament of a tungsten lamp depends on the diameter of the wire and the way in which it is coiled and mounted, the gas used in the lamp, and the life for which it is designed. Thus, the 500-watt lamp for general lighting purposes has a filament that operates at a temperature of 2940°K, while that of the 40-watt lamp operates at a temperature of about 2710°K. Both of these are designed for 1000 hrs. life. On the other hand, while the filament of the 500-watt lamp for general lighting purposes, designed for 1000 hrs. life, operates at a temperature of 2940°K, the filament of the 500-watt CX lamp operates at a temperature of about 3025°K and has a life of about 500 hrs., and the monoplane filament of the 500-watt lamp for projecting moving pictures operates at a temperature of about 3250°K with a life of about 100 hrs. These differences in temperature of operation adapt these lamps to their different uses. In projecting moving pictures, efficient production of light is much more important than a long life; hence, the amount of light radiated is increased by using a filament which operates at a higher temperature than normal for

lamps for general use. The life of the lamp is, of course, shorter, as the useful life of a tungsten lamp decreases very rapidly with increase in temperature.

The spectral radiant energy of wave lengths between 3500 and 26,000 Å was measured (*17*) for a number of representative

TABLE 14

Operating characteristics of a number of lamps

LAMP (WATTS)	LUMENS PER WATT	COLOR TEMPERATURE	LUMINOUS INTENSITY[1] (CANDLES)
40	11.1	2760°K	30
100	15.5	2865	93
500	20.	2960	590
1000	20.7	2990	1700
1500	22.0	3025	3200
900 Projection 30V-30A	26.5	3200	2700
500 Projection	26.3	3190	1500
500 CX	21.1	3015	800
250 CX	19.0	2950	370
60 CX	13.7	2825	56
6V, 21 cp. auto headlight		3015	23
Photocell exciter[2]			
7.5V		3055	560
6.0V		2640	140
Photoflood			
250W	35.8	3475	2300
1000W	31.6	3360	5500

[1] This is the horizontal candlepower in the direction in which the spectral intensities were measured.

[2] This lamp has a horizontal coil of about 12 turns, and is in a tubular bulb about 1 inch in diameter and 2 inches long.

lamps. For these measurements, the quartz double monochromator previously described (*18*) was used. The measuring device for the infrared and part of the visible was a thermopile; for the rest of the spectrum, it was a photoelectric tube. Some of the operating characteristics of these lamps are shown in Table 14, and the spectral intensities are shown in Tables 15 and 16. The values given in Tables 15 and 16 are the microwatts

that fall upon a square centimeter one meter from the lamp for a 50 Å wave length interval for the wave length indicated. In the case of lamps having the filament in one plane, the energy

TABLE 15

Spectral radiant intensities[1] *for a number of 115-volt lamps for general lighting purposes*

WAVE-LENGTH (A)	LAMP WATTAGE				
	1500	1000	500	100	40
3500	1.15	0.75	0.225	0.030	0.0075
4000	4.05	2.22	0.700	0.098	0.0245
4500	9.0	5.0	1.55	0.238	0.067
5000	15.5	8.7	2.65	0.435	0.127
5500	22.2	12.7	3.95	0.66	0.200
6000	29.7	16.7	5.5	0.89	0.260
6500	36.0	20.1	6.5	1.12	0.355
7000	41.5	21.6	7.6	1.31	0.43
7500	45.5	25.5	8.5	1.47	0.48
8000	48.5	27.5	9.2	1.60	0.52
8500	50.5	28.8	9.6	1.70	0.56
9000	51.5	29.4	10.0	1.75	0.58
9500	52.0	29.2	10.2	1.80	0.60
10000	51.8	29.0	10.5	1.81	0.62
10500	51.0	28.7	10.1	1.82	0.62
11000	49.8	28.3	9.9	1.78	0.61
12000	45.7	26.5	9.3	1.69	0.60
13000	41.5	24.0	8.6	1.57	0.55
14000	36.8	21.2	7.7	1.43	0.50
15000	31.8	18.8	6.7	1.28	0.45
16000	27.5	16.5	5.8	1.14	0.40
17000	23.9	14.2	5.0	1.00	0.35
18000	20.8	12.5	4.7	0.87	0.31
19000	17.9	10.8	3.7	0.76	0.27
20000	15.5	9.5	3.3	0.66	0.24
22000	11.6	7.3	2.6	0.52	0.19
24000	8.7	5.5	2.1	0.39	0.15
26000	6.5	4.4	1.8	0.31	0.12

[1] Microwatts per square centimeter at one meter per 50A.

radiated perpendicular to the plane of the filament was measured; for the other lamps, the radiation perpendicular to the plane of the leads was measured with the leads turned away from, and the center of the filament turned toward, the spectrometer.

TABLE 16

Spectral radiant intensities[1] *for a number of lamps for special purposes*

WAVELENGTH (A)	LAMP WATTS									
	900[2] Movie	500[2] Projection	500[2] CX	250[2] CX	60[2] CX	6.4 v[7] auto headlight	10 v[4] Photocell Exciter		Photoflood	
							7.5[5]	6.0[6]	250[2]	1000[3]
3500	1.01	0.56	0.35	0.16	0.019	0.00104	0.065	0.008	0.45	1.90
4000	4.1	2.25	1.00	.48	.062	.00301	.200	.024	1.05	4.90
4500	8.2	4.7	2.20	1.04	.145	.0062	.405	.071	1.75	9.30
5000	13.5	7.5	3.73	1.76	.248	.0105	.67	.140	3.05	14.3
5500	18.8	10.7	5.4	2.52	.41	.0157	.99	.235	3.90	19.3
6000	23.5	13.4	7.1	3.58	.56	.0206	1.30	.355	4.60	23.0
6500	27.3	15.6	8.5	4.44	.69	.0257	1.57	.46	5.10	25.8
7000	30.4	17.5	9.7	5.07	.81	.0301	1.87	.56	5.50	28.1
7500	32.8	18.6	10.7	5.55	.90	.0332	1.90	.66	5.70	29.4
8000	34.4	19.5	11.5	5.95	.99	.0357	2.00	.74	5.75	29.8
8500	35.2	19.9	12.0	6.25	1.04	.0374	2.05	.80	5.70	29.9
9000	35.5	20.0	12.3	6.42	1.08	.0380	2.08	.86	5.60	29.6
9500	35.3	19.9	12.4	6.50	1.11	.0382	2.07	.90	5.40	29.0
10000	34.6	19.5	12.4	6.52	1.13	.0381	2.06	.92	5.20	28.2
10500	33.7	19.0	12.2	6.52	1.13	.0380	2.02	.94	5.00	27.0
11000	32.3	18.5	11.8	6.44	1.12	.0375	1.95	.94	4.70	25.7
12000	30.0	17.0	11.0	6.12	1.04	.0355	1.80	.91	4.20	23.1
13000	27.2	15.4	9.9	5.45	.98	.0350	1.65	.85	3.75	20.5
14000	24.0	13.6	9.0	4.85	.90	.0292	1.45	.79	3.25	18.1
15000	21.0	11.9	7.8	4.33	.80	.0258	1.30	.71	2.80	15.8
16000	18.3	10.2	6.8	3.62	.71	.0222	1.14	.63	2.40	13.6
17000	16.1	8.4	5.7	3.15	.62	.0191	1.00	.57	2.05	11.6
18000	13.8	7.6	5.1	2.74	.54	.0166	.87	.51	1.70	9.9
19000	12.0	6.4	4.3	2.39	.47	.0144	.76	.45	1.50	8.4
20000	10.5	5.5	3.8	2.09	.40	.0126	.67	.40	1.30	7.2
22000	8.7	4.2	2.9	1.63	.31	.0098	.53	.31	1.00	5.6
24000	6.4	3.4	2.2	1.26	.24	.0078	.39	.25	.75	4.6
26000	5.1	2.8	1.7	1.04	.20	.0066	.30	.19		

[1] The values given are the microwatts per 50A that fall upon one square centimeter at a distance of one meter from the lamp.

[2] 30-volt, 30-ampere lamp.

[3] 115-volt lamp.

[4] 10-volt, 7½ ampere lamp.

[5] Operated at 7.5 amperes—see note 2, table 14.

[6] Operated at 6.0 amperes.

[7] 21 candlepower lamp.

The relative spectral distribution would probably be very nearly the same in any direction, but absolute magnitudes of the spectral intensities would vary with direction in the same ratio as the luminous outputs.

The spectral radiant intensities from a tungsten ribbon filament as transmitted through a hard glass bulb one mm. thick are given for a number of temperatures and for a range of wave lengths in Table 17.

The relative spectral distribution within the visible spectrum can be calculated from the color temperature of the filament of the lamp. The distribution thus found agreed within the experimental error with the measured values. The luminous intensity calculated from the spectral intensity values also agreed within the experimental error with the values measured by visual photometry. As a check, the spectral intensity in the visible spectrum of three high-intensity incandescent lamps (30V, 30A movie lamps, operated at 25A) that had been standardized for horizontal luminous intensity by the National Bureau of Standards was measured with the same apparatus. The luminous intensity obtained from the spectral intensities agreed with the Bureau's value to within 2 per cent.

It cannot be said that the spectral radiation of the different lamps is that of tungsten at the temperature of operation of the filament for these reasons: the absorption of the glass bulb very markedly changes the distribution for wave lengths greater than about 2.5 μ; the filament is not all at the same temperatures, due to end cooling, etc., which means that the measured distribution is approximately that for some average temperature; and the inter-reflection between adjacent coils makes the radiation that comes from between the coils more nearly like that from a black body at the same temperature as the coils. Thus the radiation of the lamp is made up in part of radiation characteristic of tungsten, and in part of radiation with a spectral distribution somewhere between that of tungsten and that of a black body at the temperature of the filament.

It is somewhat difficult to estimate the accuracy of these results. However, it is thought that the values of the spectral

radiation in the central portion of the spectrum will be at least reproducible to plus or minus 3 per cent, while those at the ends of the spectrum are much less accurate.

TABLE 17

Spectral steradiance of tungsten ribbon as observed through 702 P glass bulb one mm. thick

(Values as given are watts per square centimeter of radiation surface per unit solid angle per 100A.)

WAVE-LENGTH	TEMPERATURE					
	3300°K	3000°K	2800°K	2700°K	2600°K	2150°K
3500	.049	.0145	.0054	.0032	.0017	.000066
4000	.142	.0490	.0216	.0128	.0077	.00045
4500	.261	.1035	.0466	.0309	.0196	.00161
5000	.402	.172	.0858	.059	.0394	.00417
5500	.537	.248	.133	.0946	.0654	.0085
6000	.660	.326	.184	.1345	.096	.0148
6500	.756	.393	.234	.1755	.1285	.0227
7000	.825	.447	.279	.212	.160	.0317
7500	.867	.487	.302	.245	.188	.0414
8000	.889	.516	.344	.273	.211	.0509
8500	.887	.531	.364	.291	.230	.0596
9000	.880	.545	.377	.306	.244	.0682
9500	.854	.524	.381	.312	.252	.0748
10000	.818	.512	.379	.3125	.257	.0804
10500	.778	.495	.372	.310	.256	.0834
11000	.736	.471	.361	.304	.253	.0869
12000	.648	.419	.334	.283	.238	.0889
13000	.564	.370	.302	.258	.218	.0870
14000	.489	.321	.267	.230	.195	.0826
15000	.418	.278	.234	.201	.173	.0763
16000	.365	.242	.203	.176	.153	.0742
17000	.303	.222	.176	.152	.133	.0611
18000	.259	.183	.149	.130	.114	.0556
19000	.222	.159	.1255	.112	.0988	.0496
20000	.190	.136	.1115	.097	.0854	.0433
22000	.136	.101	.0846	.074	.0648	.0337
24000	.102	.069	.0640	.0564	.0496	.0260
26000	.0760	.058	.0475	.0427	.0380	.0201
30000	.0275	.0235	.0196	.0178	.0161	.0088
35000	.0119	.0107	.0091	.0084	.0077	.0041
40000	.0030	.0025	.0021	.0019	.0017	.0010

The spectral emissivity of tungsten for wave lengths greater than 5 μ is small but appreciable (15 per cent for a temperature of

2900°K and a wave length range between 5 and 6 μ), but the lamp bulb is practically opaque to radiation of these wave lengths. Thus, for wave lengths longer than 5 μ, the radiation is that of hot glass. The amount of this radiation varies because the bulbs of the different lamps operate at different temperatures. The bulb must be at such a temperature that it can get rid of the energy it receives from the gas within the bulb and also of the direct filament radiation which it absorbs. For most lamps, the absorbed radiation amounts to about 5 per cent of the input. The amount of energy that the gas carries to the bulb varies from about 25 per cent of the input for the 40-watt lamp to about 7.5 per cent for the 500-watt lamp. The bulbs of lamps for general lighting purposes operate at temperatures between 150 and 200°C., and the bulbs of some of the special lamps operate at temperatures of 300 to 400°C.

LAMP CHARACTERISTICS AND VOLTAGE

When the voltage applied to an incandescent lamp is changed, the various lamp characteristics change in varying amounts (*19*). A study of the characteristics of a number of three different sizes of representative 115-volt gas-filled lamps (40-watt, 100-watt, and 500-watt lamps) for a range of voltage has been made (*20*), and the results are shown in Table 18.

In two of these lamps, the filaments are regularly mounted in inside-frosted bulbs. However, for measurement of the temperatures, the filaments were mounted in clear glass bulbs and a correction was made for the absorption of the glass so that the temperatures given are the actual true temperature of the hottest part of the filaments.

LAMP CHARACTERISTIC EQUATIONS

The temperature, current and lumen output of the lamps for the range of voltage were measured directly. These measured values were checked and the life variation given was calculated using certain established relations between the various characteristics and the voltage. The engineers at the National Bureau

TABLE 18

Variations of lumens, lumens per watt, watts, temperature, and life, with voltage of 40-, 100- and 500-watt 115-volt gas-filled tungsten lamps

LAMP	VOLTS				
	105	110	115	120	125
40-watt					
Current (amp)	0.333	0.341	0.348	0.356	0.364
Temperature (°K)	2625	2663	2710	2756	2801
Lumens per watt	8.94	9.32	11.1	12.19	13.32
Per cent watts	87.5	93.8	100	106.6	113.7
Per cent lumens	70.8	84.9	100	117.4	136.4
Per cent life	432	201	100	52	28
100-watt					
Current (amp)	0.830	0.850	0.870	0.890	0.910
Temperature (°K)	2753	2799	2845	2890	2934
Lumens per watt	12.90	14.19	15.45	16.82	18.15
Per cent watts	87.1	93.5	100	106.8	113.7
Per cent lumens	72.5	85.6	100	115.8	133.4
Per cent life	373	189	100	55	31
500-watt					
Current (amp)	4.135	4.245	4.345	4.450	4.550
Temperature (°K)	2847	2900	2950	3000	3048
Lumens per watt	17.05	18.55	20	21.48	22.90
Per cent watts	86.9	93.4	100	106.8	113.8
Per cent lumens	74.1	86.5	100	114.6	130
Per cent life	328	178	100	58	35

TABLE 19

Some operating characteristics of gas-filled tungsten lamps

LAMP	EFFICIENCY IN LUMENS PER WATT	FILAMENT TEMPERATURE (°K)	PER CENT OF INPUT RADIATED WITHIN VISIBLE SPECTRUM	END LOSS, PER CENT OF INPUT CONDUCTED AWAY BY LEADS AND SUPPORTS	GAS LOSS, PER CENT OF INPUT	PER CENT INPUT RADIATED BEYOND BULB BY FILAMENT	LOWERING OF EFFICIENCY DUE TO END LOSS (PER CENT)
40-watt	11.1	2710	6.8	1.6	24.5	66.8	3.8
60-watt	12.9	2770	7.6	1.6	22.2	69.1	3.9
100-watt	15.5	2845	9.3	1.7	18.5	72.8	4.1
150-watt	16.9	2865	9.6	1.7	16.1	75.1	4.1
200-watt	17.2	2880	10.2	1.7	13.7	77.4	4.2
300-watt	18.5	2915	10.7	1.8	11.6	79.8	4.3
500-watt	20.0	2950	11.4	1.8	9.2	82.3	4.3

of Standards have published (*21*) equations that show these relations in the following form:

$$\text{Log}\left(\frac{L}{L_0}\right) = A \log\left(\frac{V}{V_0}\right) + B \log^2\left(\frac{V}{V_0}\right) \tag{11}$$

If the proper coefficients are used for the lamp studied, these equations give results that check with measurements over a wide range of voltage.

The lamp engineer uses an equation similar to the above, but neglects the squared term on the right, which may be written in the following form:

$$L = K_1 V^{-d} = K_2 E^{-b} \tag{12}$$

$$lu = K_3 V^k \tag{13}$$

where L is the life in hours, V the voltage, E the efficiency in lumens per watt, lu the lumens, K a constant, d, b, and k being so-called constant exponents. The values of these various exponents were determined from the accumulated data on the various characteristics obtained in the Testing Section at Nela Park. In general such exponents vary with the lamp size and the applied voltage, so for the highest accuracy the exponent corresponding to the voltage range investigated should be used. The exponent b varies from about 6.8 for 40-watt gas-filled lamps to about 7.6 for the 500-watt gas-filled lamps. The variation of this exponent with voltage is about 3 units in the second decimal place for a 5-volt change for a 40-watt 115-volt lamp, and about 2 units in the first decimal place for a 5-volt change for a 500-watt 115-volt lamp. The exponent d changes from about 15.4 for a 40-watt lamp to about 12.8 for a 500-watt lamp. The voltage variation for this exponent is about -3 units in the first decimal place for a 5-volt change for a 40-watt lamp and about -2 units in the first decimal place for a 5-volt change in the 500-watt lamp.

The exponent k varies from about 3.78 for the 40-watt lamp to 3.23 for the 500-watt lamp. The variation of this exponent with wattage is about constant with a variation of about -1 part in the first decimal place for each change of 5-volts. Know-

ing the value of these and other exponents and how they vary with different operating conditions, the change in the more important characteristics with a change in the voltage can be calculated.

In Tables 19 and 20 are given some characteristics of a number of incandescent lamps that are now used for general lighting. For low-wattage lamps, the use of the metal tungsten, which has a comparatively low specific resistance, as the filament material, requires a long filament of very small diameter. As is shown in

TABLE 20

Additional characteristics of tungsten lamps

LAMP	APPROXIMATE FILAMENT DIAMETER (MM)	FILAMENT WEIGHT (MILLIGRAMS)	FILAMENT HEAT CONTENT (JOULES)	MODULAR* TIME (SEC.)	HEATING TIME TO 90 PER CENT LUMENS (SEC.)	COOLING TIME TO 10 PER CENT LUMENS (SEC.)	RANGE OF VARIATION IN LIGHT OUTPUT (PER CENT)	
							60 Cycles	25 Cycles
40-watt	0.035	6	2.5	0.06	0.07	0.03	14	23
60-watt	0.045	13	5.5	0.09	0.10	0.04	13	21
100-watt	0.065	31	12.8	0.13	0.13	0.06	12	20
150-watt	0.085	64	26.5	0.18	0.18	0.08	9	18
200-watt	0.100	95	39.5	0.20	0.22	0.10	8	17
300-watt	0.130	185	80.0	0.27	0.27	0.13	6	15
500-watt	0.200	420	182.0	0.36	0.36	0.19	4	12

* The time required for the normal input of the lamp to supply the amount of energy stored in the filament when it is at normal operating temperature.

Table 20, the diameter of the filament ranges from about 0.04 mm. for the 40-watt 115-volt lamp to about 0.2 mm. for the 500-watt 115-volt lamp. The filament of the 40-watt 115-volt lamp is about 40 cm. long, and the filament of the 500-watt 115-volt lamp is somewhat more than twice this length.

HEAT CONTENT OF THE FILAMENT

Although the amount of material in the different sized filaments is small, ranging from about 6 milligrams for the 40-watt lamp to about 420 milligrams for the 500-watt lamp, the temperature of operation is so high that the heat content of the filament at the operating temperature is appreciable, ranging as

shown in Table 20 from about 2.5 joules for the 40-watt lamp to nearly 200 joules for the 500-watt lamp.

DISSIPATION OF ENERGY BY LAMP FILAMENT

As the incandescent lamp is operated on a continuous supply of energy, it is necessary for the filament to dissipate the energy it receives at this same rate after the steady state is reached. The filament dissipates its energy by three methods: by its own radiation, by conduction and convection of the surrounding gas, and by conduction of the leads and supports. About 5 per cent of the energy radiated by the filament is absorbed by the bulb and lost by the radiation of the bulb and by the conduction and convection of the surrounding air. The values given in Table 18 for the amount of the input radiated beyond the bulb takes account of this bulb absorption. Table 19 gives the percentages of the input energy that are dissipated by each of the foregoing methods. As has been previously mentioned, the more a material's energy is radiated within the visible spectrum, the more satisfactory it is for an incandescent lamp filament.

Table 19 also shows the percentage of the radiated energy within the visible spectrum for these tungsten lamps.

CALCULATION OF MODULAR TIME

It is interesting to calculate, from the heat content of the filament at normal operation temperature, the time required for the regular rate of input of energy to supply the amount of energy that is stored up in the filament at normal temperature. This time is shown in Table 20 and may be called the modular time. These modular times are not the times necessary for constant applied wattage to raise the filament to temperatures of normal operation, because as soon as the filament is raised to a temperature higher than its surroundings, it begins to lose energy by the methods already mentioned, and these losses increase the amount of energy necessary and thus the time required to reach the normal temperatures. Under conditions of constant applied voltage the filament will heat up somewhat more rapidly as the energy is applied at a greater rate. For constant current, how-

ever, the filament will heat somewhat more slowly than at constant wattage, since this represents a slower supply of energy. This is due to the fact that the filament has a lower resistance when cold than when hot.

The times required, after the application of voltage, for a number of different sized lamps to reach such a temperature that they gave off 90 per cent of their light output at normal temperature, as well as the times required, after the applied voltage is turned off, for their filaments to cool to such a temperature that the lamps gave off 10 per cent of their normal light output, are shown in Table 20. A considerably longer time would be required for the filament to cool to room temperature after the applied voltage is removed, as the rate of cooling decreases as lower temperatures are reached.

FACTORS AFFECTING LIGHT OUTPUT

When an incandescent lamp is operated on alternating current, the temperature of the filament, and thus its light output, changes as the current passes from its maximum value to zero. The resulting cyclic variation in the light output for 60-cycle alternating current is too rapid to be observed directly, but by using special methods it can be measured. Table 20 gives the percentage variations about the mean in the light output of a number of incandescent tungsten lamps when operated on 60-cycle and on 25-cycle alternating current. These changes in the lumen output of the lamps on 60-cycle alternating current correspond to a change in temperature of the filament from about 80°C. for the 40-watt lamp to about 30°C. for the 500-watt lamp.

It is to be noted that the time of heating and cooling and variation of light output all depend on the filament diameter in such a manner that the larger the diameter of the filament, the more the filament apparently resists any change in its temperature. The larger filaments heat and cool more slowly than the smaller filaments, and the cyclic variation of the light output as the alternating current changes from its maximum value to zero is less for the large filaments than for filaments of smaller diameter.

Any change in the voltage applied to an incandescent tungsten lamp will be followed more or less rapidly by a change in the light output of the lamp, and this change in light output will asymptotically approach the static conditions—that is, the condition of temperature and light output of the lamp if it were operated continuously at the new voltage. Calculations, which are in good agreement with measurements, show that the time required for the light output of the filament to reach a point that differs from its final value by 1/e, or 37 per cent of the total change due to the change in voltage, is substantially independent of the magnitude of the change in voltage. For the range of wire size considered in Table 20, this time is about 40 per cent of the modular time, which is the time required for the entire wattage of the lamp to supply an amount of energy equivalent to the heat content of the filament at the operating temperature.

Thus, a change of five volts in the lamp voltage, which will produce eventually a change of about 15 per cent in the light output, will produce about 10 per cent (63 per cent of 15 per cent) change in the light output in a time ranging from 1/40 sec. for a 40-watt lamp to 1/7 sec. for a 500-watt lamp. (These are 40 per cent of the modular times for these lamps as given in Table 20.) If the time of change to the new voltage and back to the original voltage is small (as compared to 1/40 sec. for the 40-watt 115-volt lamp and 1/7 sec. for the 500-watt 115-volt lamp), the resulting light change will be less than 63 per cent of that corresponding to the static change, while any voltage change that takes a longer time than this will result in a change of light output greater than 63 per cent of the static change.

This calculation does not take into account the heat content of the gas sheath surrounding the filament, the effect of which will be proportionally greater for the lower wattage lamps and may cause an increase in the times given of as much as 10 per cent for the 40-watt lamp.

FLICKERING OF LAMPS

Experience has shown (*22*) that a sinusoidal change in light intensity of less than about 10 per cent can not be noticed for any

frequency of alternation, although a larger frequency change will be noticeable for a range of frequencies between limits one greater and one less than four cycles per second; for example, a 10 per cent change in the light output will show no flicker for frequencies greater than about seven cycles per second or less than two cycles per second. A small abrupt change in the light intensity can be noticed when the change in the light output is of the order of photometric accuracy—that is, about one per cent.

Some time ago, because of the operation of special devices, the voltage in the laboratory periodically dropped about 3 per cent for about two cycles as shown by measurements made with an oscillograph. This change in the voltage for this period produced a flicker in the light output (a maximum change of about 2 per cent) of a 200-watt tungsten lamp that was easily noticeable after one's attention was called to it. To test this, a change of 3 per cent for two cycles was produced in the voltage applied to a 200-watt lamp by the use of a welding timing device devised in this laboratory. This produced a flicker that was easily noticeable. Some of the observers could see the light flicker produced when the voltage applied to a 200-watt lamp was changed by about two volts in 115 volts for a period of only two cycles.

LAMP EFFICIENCY AND LAMP VOLTAGE

Since lamps for general lighting purposes are made for various voltages from the 32-volt lamp for country home lighting to the so-called high-voltage lamp of 230 volts, the question arises at what voltage would a lamp of a certain wattage have the maximum efficiency in lumens per watt. By calculation, using the characteristics of the lamps of different sizes, that is, different wattages, and making corrections for lead loss, support loss, etc., the efficiency of a 100-watt, a 60-watt, and a 40-watt lamp for a range of voltages was calculated and the results shown in Figure 10. These results show that for lamps of this size the maximum efficiency is found from about 20 to about 12 volts. This is in keeping with the above statement that lamps with large filaments can be operated at a higher temperature and thus at a higher

efficiency than lamps with smaller filaments, and also that the per cent gas losses are smaller for large filaments than for small ones. The reason for the drop in efficiency at lower voltages is due to the more or less constant loss due to the supports that have to be considered. This analysis takes no consideration of some other problems such as the expense of wiring the building with larger wires and the inevitably greater line drop for the higher currents which would probably more than make up for the gain in efficiency of the lower voltage lamps. If all of these

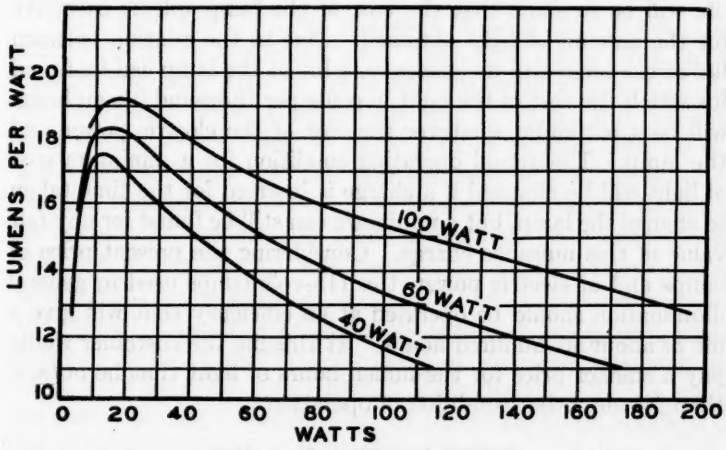

FIG. 10. Lumens per watt for different voltage incandescent lamps (40-watt, 60-watt, and 100-watt lamps).

things are taken into consideration, the result will show that a voltage somewhere in the neighborhood of 115 would be the most efficient.

MOST ECONOMICAL LIFE FOR INCANDESCENT LAMPS

Just why one thousand hours has been selected as the standard life of incandescent lamps is difficult to say. The customer is not only buying lamps but is also buying electric power for the purpose of obtaining light, and he should use the lamps and electric power to the best advantage possible. It is obvious that if

the electric power cost nothing the lamps should be burned for a very long life, the life in this case being determined by the quality of the light desired. On the other hand, if the lamps cost nothing, they should be so operated as to have a very short life, the life in this case being determined by the value placed upon the time necessary to change the lamp. Since one pays for both the lamp and the electric power, some compromise is necessary. It is possible to operate the lamp at such an efficiency that the life will be so long that the cost of power will be excessive for the light obtained, or again, the lamp may be so operated that the life will be so short that the cost of the lamp will be excessive for the amount of light obtained. Due to the relation between life of the lamp and its efficiency, a life of the lamp can be found for which the cost of the light in cents per thousand lumen hours will be a minimum whatever the cost of the electric power and the lamp. The actual operating condition for a minimum cost of light will be changed if a charge is inserted for the time taken to change the lamp, but a minimum can still be found for any fair value of this nuisance charge. Considering the present price of lamps and of electric power, the 115-volt lamps used in general illumination should be operated at an efficiency that will give a life of about six hundred hours. At this life the customer would pay a smaller price for the lumen hours of light that he obtains than for any other condition of operation.

INSIDE FROSTING OF LAMPS

To reduce the glare from the bright filament it has been the custom for a long time to frost or enamel the outside of the lamp bulb. There are two objections to this method of reducing the glare. One is that the frost being on the outside of the bulb is somewhat rough and it is very difficult to clean, and also it was found that these frosted and enameled bulbs even when clean absorb from 5 to 20 per cent of the light from the lamp, and this absorption of light might be very high when the bulb becomes covered with dirt. It was early recognized that if the bulb were frosted on the inside it would be much easier kept clean, but the early attempts at this failed, because the bulb frosted on

the inside was very much weaker than if frosted on the outside. One of the lamp engineers (*23*) studied this problem and devised a means of frosting the lamp on the inside in such a manner that the bulb is practically as strong after frosting on the inside as it was before. The absorption due to the inside frost amounts to, in general, about one per cent of the light from the lamp. Thus the replacement of the outside frost by this inside frost has resulted in a saving of 4 to 5 per cent in efficiency over the old outside frost bulb, and at the same time has given us a lamp that can be cleaned as readily as the clear bulb.

Some time ago the lamp engineers decided that it would be advantageous to replace all clear bulbs with inside frost bulbs, and at the same time to use coiled filaments for some of the vacuum lamps rather than the customary straight wire, because this would permit them to make a much smaller bulb for the same wattage lamp. At the time they started they expected to make a vacuum lamp with coiled filament that would be about as efficient as the straight filament vacuum lamp that it was intended to replace. It was known that a coiled filament was inherently a poorer source of light than the straight filament when they were both operated at the same temperature, because, while tungsten radiates selectively in favor of the short wavelengths, when the filament is coiled part of the radiation from the space between coils approximates that of the black body, which is a less efficient producer of light than tungsten. The loss in efficiency due to the partial black body radiation from the inside of coils and the small amount of light absorbed by the inside-frosted bulb combine to lower the efficiency of a vacuum lamp with a coiled filament. However, there are other factors that tend to increase the efficiency. Two of the latter are outstanding. The rate of evaporation from a coiled filament is considerably less than that from a straight filament at the same temperature, because many of the tungsten molecules that leave the inside of the coils strike the filament and are unable to escape. This difference permits the operation of the coiled filament at a higher temperature for the same life. As previously mentioned, the coiling of the filament permits the number of supports to be

reduced from nine to three, and this change results in about a three per cent increase in efficiency.

Another factor gives an additional though slight gain in efficiency. Because of the mutual heating effect between coils, the same current will heat a coiled filament to a higher temperature than the corresponding straight wire. This means that with coiled filaments a slightly larger filament can be used for the same temperature and the same wattage. As pointed out above, the life of a lamp at a definite temperature depends upon the cross-section of the filament. Thus, the use of the larger filament permits it to be operated at a slightly higher temperature for the same life, and this results in an increase in efficiency.

The combined effect of these properties of the coiled filament and inside frosting was a gain in efficiency for the new inside frosted lamp with a coiled filament over the old straight filament type of tungsten lamp in a clear bulb.

THE EYE AND LAMP EFFICIENCY

Now why is all this effort being expended in an attempt to increase the efficiency of the light source, and what is the reason for all the agitation about such increases in efficiency? The reason for this is that of all the problems demanding the attention of engineers today, the one connected with the light source offers the greatest opportunities for improvement, since the light source is probably the least efficient, from the standpoint of the ultimate, that is obtained by any of the converters of energy.

Light, which is radiant energy evaluated according to its capacity to produce visual sensation, is thus tied up with the sensitivity of the eye for radiant energy of different wave lengths. Fixing the value of the lumen, which is the total flux from a source of one mean spherical candlepower, together with the fixed value of the watt, fixes the maximum efficiency of a light source in lumens per watt.

To obtain light at this maximum efficiency, it is necessary to find some method of converting electrical energy into radiation at the wave length where the average eye is the most sensitive, which experiment has shown to be in the yellow-green at wave

lengths about 5550 Å. The maximum luminous efficiency has been found by experiment to be 620 lumens per watt, a direct result of the value of the watt and the definition of the lumen or the candle upon which the lumen is based. The constant, 620 lumens per watt, is the relation between two different kinds of units, the lumen and the watt, just as the mechanical equivalent of heat is the relation between the joule and the calorie. When it is remembered that the present-day light sources range in efficiency from about 10 to 25 lumens per watt, it will be noted that for these light sources the percentage of maximum possible efficiency is indeed low, ranging from about 1.6 per cent to about 4 per cent. The light from a source operating at this maximum efficiency would be a yellow-green in color, which would not be satisfactory for general purposes.

If we consider a black body as a source of light, and operate it at a temperature at which it has the maximum efficiency, the result will be a white light at an efficiency of about 85 lumens per watt, when the black body is at a temperature of about 6700°K. This results from the fact that as the temperature of a radiator is raised, the maximum of the radiation shifts toward shorter and shorter wave lengths. This at first gives an increase of the percentage of the energy within the visible spectrum, and with still higher temperature the maximum of this energy moves to the ultraviolet, which reduces the percentage radiated in the visible spectrum, and thus the efficiency. This efficiency of 85 lumens per watt might be increased somewhat if it were possible to eliminate the infrared and ultraviolet radiation that are not used for producing the light. If the ultraviolet were eliminated for wave lengths shorter than 4000 Å and the infrared for wave lengths longer than 7600 Å, the efficiency would be increased to about 200 lumens per watt. This efficiency might be increased up to as much as 250 lumens per watt without very greatly changing the color of the light by changing these limits, the one towards longer wave lengths and the other towards shorter wave lengths. Since other sources are at least as efficient as the black body, a marked gain in efficiency would result if light sources could be operated at a very high temperature, and if, in addition

to this high temperature operation, some method could be devised to eliminate the ultraviolet and particularly the infrared radiation, another increase of a factor of 2 or 3 would result. Quite unfortunately no one knows how to make a black body or any other source that can be operated at a temperature of 6700°K, and thus obtain the 85 lumens per watt and white light, nor is it known how to suppress the ultraviolet and infrared part of the spectrum, thus increasing this by a factor of 2 or 3.

The amount of energy within the limits of the visible spectrum for the various tungsten lamps is small. In column 4 Table 19 are given the percentages of the input energy that is radiated within the limits of the visible spectrum for several different wattage lamps. From this it is seen that the lamp engineer has

TABLE 21

Comparative measurements on 40-watt lamps

LAMP	DATE MEASURED	TEMPERATURE	EFFICIENCY IN LUMENS/WATT
40-watt squirted filament	1907	2310°K	7.8
40-watt drawn wire	1909	2320°K	8.9
40-watt vacuum	1931	2565°K	10.8
40-watt gas-filled	1936	2710°K	11.1

plenty of incentive to attempt to find a source that will radiate more favorably than the tungsten lamp, that is, a source that would give a larger percentage of its radiation in the visible spectrum. There is also plenty of work to be done in reducing some of the losses, in addition to the work necessary in studying designs and methods of manufacture. Such changes are continually going on. As an illustration of the progress made by the lamp industry the following example is given: At about 1909 or 1910, the temperature and efficiency of some 40-watt tungsten lamps with squirted and drawn wire filaments were measured (*24*). The results are given in Table 21, together with data on the present 40-watt lamp for comparison. Like improvements have been made in other wattage lamps. An increase of 30 per cent in efficiency of one type of lamp over a period of about thirty years may not seem large, but when applied to the total light bill of the country its value becomes quite significant.

FUTURE POSSIBILITIES

Can predictions be made for similar increases in the efficiency of tungsten lamps in the future? It seems so. Coiled coil filaments will most certainly be made in the 40-watt 115-volt size with an efficiency at least 15 to 20 per cent greater than the present-day lamp. Beyond that? Maybe some of the filamentless lamps will give us the next step. Already one hears claims for very high efficiency for sodium vapor lamps, special mercury vapor lamps, and even for some of the fluorescence lamps.

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